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K-10

AMMONIA SLIP CATALYTIC

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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

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AMMONIA SLIP CATALYTIC

1 Application

The Guideline applies to the ammonia slip catalytic (hereinafter referred to as ASC) for engine exhaust after-treatment systems applying for the approval and survey by China Classification Society (hereinafter referred to as CCS).

2 Normative references

2.1 The approval and inspection bases referred to in the Guidelines are as follows:

2.1.1 Part 1, Chapter 3, Rules for Classification of Sea-going Steel Ships of China Classification Society

2.1.2 Guidelines for Ships Using Ammonia Fuel of China Classification Society

2.1.3 Guidelines for Approval and Survey of Selective Catalytic Reduction (SCR) System of China Classification Society

2.2 The approval and inspection bases referred to in the Guidelines are as follows:

2.2.1 IMO MEPC.177(58) NO_x Technical Code 2008 and its amendments

2.2.2 IMO MEPC.291(71) 2017 Guidelines Addressing Additional Aspects of the NO_x Technical Code 2008 with Regard to Particular Requirements Related to Marine Diesel Engines Fitted with Selective Catalytic Reduction (SCR) Systems and its amendments such as MEPC.313(74)

The referenced documents for the application of this Guidelines, for dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

3 Terms and definitions

3.1 Terms and definitions

- (1) Ammonia slip catalyst (ASC) : It means a catalytic converter or device used in the exhaust after-treatment system for ammonia-fueled engines, which reduces ammonia (NH₃) slip in engine exhaust through catalytic oxidation.
- (2) SCR chamber: It means a catalytic converter, which is an integrated unit contains the catalyst block that can facilitate the reduction reaction between NO_x in exhaust gas and reductant to generate N₂ and H₂O. It is the core part of the SCR system.
- (3) Catalyst block: It means a block of certain dimension through which exhaust gas passes and which contains catalyst composition on its inside surface to reduce NO_x from exhaust gas.
- (4) Space velocity (SV) value: It means a value of the exhaust gas flow rate passing through the catalyst block(s) (m³/h) per total volume of the catalyst block(s) in the ASC chamber (m³). Therefore, unit of SV value is (1/h). The exhaust gas flow volume is the volume defined at 0 °C and 101.3 kPa.

- (5) Area velocity (AV) value: It means a value of the exhaust gas flow rate passing through the catalyst blocks (m³/h) per total active surface area of the catalyst blocks in the ASC chamber (m²). Therefore, unit of AV value is (m/h). The exhaust gas flow volume is the volume defined at 0 °C and 101.3 kPa.
- (6) Linear velocity (LV) value: It means a value of the exhaust gas flow rate passing through the catalyst blocks (m³/h) per catalyst block's section (m²) in a normal direction of exhaust gas flow. Therefore, unit of LV value is (m/h). The exhaust gas flow volume is the volume defined at 0 °C and 101.3 kPa.
- (7) Total volume of catalyst block: It means the volume (m³) based on outer dimensions of the catalyst block.
- (8) Block section: It means the cross-sectional area (m²) of the catalyst block based on the outer dimensions.
- (9) Total active surface area: It means the total surface area of catalyst block measured with selective chemisorption method.
- (10) Channels Per Square Inch (CPSI): It means the number of channels per square inch on the cross section of the catalyst block.
- (11) NH₃ conversion efficiency: It means the rate of change of NH₃ emissions at the inlet and outlet of the ASC when the standard gas simulation test bench is operated under specified conditions, Unit of η is %

$$\eta(\text{NH}_3) = \left[\frac{\text{NH}_3(i) - \text{NH}_3(o)}{\text{NH}_3(i)} \right] \times 100\% \dots \dots \dots (1)$$

Where,

$\eta(\text{NH}_3)$ —NH₃ conversion efficiency, %

NH₃(i)—NH₃ concentration at the ASC inlet

NH₃(o)—NH₃ concentration at the ASC outlet

- (12) NO_x/N₂O selective conversion efficiency: It means the ratio of the selective product produced to the amount of reactant converted, calculated as follows:

$$S_1(\text{NO}_x) = \left[\frac{\text{NO}_x(o) - \text{NO}_x(i)}{\text{NH}_3(i) - \text{NH}_3(o)} \right] \times 100\% \dots \dots \dots (2)$$

Where,

S₁ (NO_x)—NO_x selective conversion efficiency, %

NO_x(i)—NO_x concentration at the ASC inlet

NO_x(o)—NO_x concentration at the ASC outlet

NH₃(i)—NH₃ concentration at the ASC inlet

$NH_3(o)$ — NH_3 concentration at the ASC outlet

$$S_2(N_2O) = \left[\frac{2 \times (N_2O(o) - N_2O(i))}{NH_3(i) - NH_3(o)} \right] \times 100\% \dots \dots \dots (3)$$

Where,

$S_2(N_2O)$ — N_2O selective conversion efficiency, %

$N_2O(i)$ — N_2O concentration at the ASC inlet

$N_2O(o)$ — N_2O concentration at the ASC outlet

$NH_3(i)$ — NH_3 concentration at the ASC inlet

$NH_3(o)$ — NH_3 concentration at the ASC outlet

- (13) Fresh state: It means the state of catalyst after pretreatment.
- (14) Aged state: It means the state of catalyst after aging.
- (15) Modeling tool: It means a simulation calculation tool adopting engine emission parameters and model test data to calculate the conversion efficiency of NH_3 , NOX , N_2O , etc.
- (16) Model test: Providing data to modeling tools, so it is called the "model test", which is referred to the content in 6.1.1.3 of MEPC291(71). It can be carried out with full-scale or scaled catalyst blocks, and mixed gas can be engine exhaust gas or simulated gas.
- (17) Scheme A: It means a survey method to carry out, during pre-certification survey, test-bed testing in accordance with Chapter 5 of the NTC 2008 or onboard testing in accordance with the full test-bed requirements of Chapter 5 of the NTC 2008 for an engine fitted with an ASC system to prove the compliance of its emission.
- (18) Scheme B: It means a survey method to prove the emission compliance of an engine through modeling calculation and on board initial confirmation test, etc. (refer to MEPC.291 (71)).
- (19) Material Safety Data Sheet (MSDS) of the catalyst: It means a sheet containing physical and chemical parameters and hazardous information about the catalyst for users' reference and to promote safe operation.

4 Drawings and documents

The following drawings and documents shall be submitted for review .

4.1 The following drawings and documents shall be submitted to CCS for approval:

- (1) ASC structure/arrangement drawing, including the installation layout of the shell and channels, catalyst blocks (and/or supports), the soot blowing device, any baffles or other devices used for exhaust gas flow distribution, sensors (especially control-related temperature and pressure sensors), gaskets, insulation layers, inspection ports, etc. It shall be able to reflect the relative position of the ASC and the engine, such as the layout of the exhaust branch pipes or manifold, and the bypass pipelines. If integrated with SCR, it shall

- also reflect the relative position with the SCR.
- (2) ASC schematic diagram, including inlet parameters and cross-unit parameters.
 - (3) Materials and specifications of major components, including the reaction device shell, pipelines, catalyst blocks, etc.
 - (4) Catalyst block (and/or support) diagrams, which shall include:
 - ① Catalyst block (and/or support) structure diagram, including the specifications, geometric dimensions, catalyst model, catalyst unit mass, material and manufacturer;
 - ② Drawing of installation and arrangement of internal catalyst block, including the quantity and arrangement of the supports, and the sealing arrangement between the supports and the ASC chamber shell structure to prevent exhaust gas leakage;
 - ③ limiting characteristics, such as CPSI ((cells per square inch) and physical parameter ranges (such as space velocity (SV), area velocity (AV) and linear velocity (LV)), and the part number or specification number specified by the applicant on the catalyst block (and/or support);
 - ④ Type of catalyst coating, coating materials, total content and ratio of precious metals, and normal operating temperature range of the catalyst.
 - (5) ASC system control strategy description (if applicable), including at least:
 - ① Control strategy flow chart, with the control mode specified;
 - ② All control related input and feedback signals.
 - (6) Main performance specifications of the product, which shall include:
 - ① Performance parameters table, i.e. applicable inlet and outlet boundary conditions and restrictions of the catalyst block (and/or support), including at least the catalyst block scaling range, exhaust gas flow rate range, space velocity and linear velocity range, NH₃ concentration range, reaction device inlet temperature range, pressure loss, and other applicable parameter ranges;
 - ② The coating type and coating materials of catalyst blocks, total content and ratio of precious metals, and normal operating temperature range of the catalyst;
 - ③ Applicable fuel quality, standards and maximum allowable sulfur content (if applicable);
 - ④ Factors related to the deterioration rate of the catalyst block, such as: moisture, O₂, ammonium salts, catalyst block replacement conditions and recommended replacement time, etc.;
 - ⑤ Catalyst block NH₃ conversion efficiency curve, NO_x selective conversion efficiency, N₂O selective conversion efficiency, other harmful pollutants (such as cyanide) (corresponding to different concentration, temperatures and space velocity, and indicating the outlet ammonia slip),

- (7) Modeling tool instructions (for Scheme B)
- (8) Modeling Calculation Report/Model Test Report (for Scheme B)
- (9) Type test program (to be provided when applying for type approval).
- (10) ASC technical files (refer to the requirements of Clause 9.1 of the Guideline, to be provided during type approval).

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

- (1) Product manual;
- (2) Samples of product nameplates, factory quality certification documents, etc.
- (3) Risk analysis, failure mode and effects analysis (FMEA).
- (4) The Material Safety Data Sheet (MSDS) of the catalyst, as well as the protective measures that shall be taken during the installation and replacement of the catalyst, and the waste recycling measures.

4.3 The drawings/ Document during type approval stage shall at least include the following:

- (1) Factory overview: factory name, address, production history, production capacity, technical and inspection personnel, main products, affiliation, product trademark, etc.;
- (2) Details of products under application;
- (3) List of main production equipment;
- (4) List of main testing equipment;
- (5) The brief production process of the product applying for approval. If the welded structure is adopted, the welding process shall be evaluated and approved according to the Rules for Materials and Welding of CCS and the standards accepted by the CCS.
- (6) Quality management documents or quality system certificates;
- (7) Enterprise registration certificate;
- (8) Qualification certificate and/or production license, if applicable;
- (9) Sample of product quality certificate or conformity certificate;
- (10) Quality control plan, if applicable.
- (11) List of suppliers of raw materials / main parts and components.

5 Technical requirements

5.1 The design operating conditions of the ASC shall meet the requirements of environmental conditions in Section 2, Chapter 1, Part 3 of the CCS Rules for Classification of Sea-going Steel Ships.

5.2 The ASC shall be designed to operate over the entire expected flow range and to achieve the ammonia conversion efficiency required by the design. The applicable exhaust gas temperature range of the ASC reactor shall be specified and shall meet the requirements of the test cycle for the corresponding engine application.

5.3 The design, manufacture and installation of the ASC shall be reasonable to prevent corrosion, oxidation and vibration that may occur in service. The operational safety shall be ensured, measures such as thermal insulation protection shall be taken, and the general protection requirements for high-temperature surfaces shall be met.

5.4 The selection of ASC materials shall meet the requirements of 5.2~5.8.

5.5 The pipeline design and manufacture of the ASC shall meet the applicable requirements of Section 2, Chapter 3 of the Guidelines for Ships Using Ammonia Fuel.

5.6 The catalyst blocks shall be sealed in the reaction device with sealing measures in place to prevent exhaust gas leakage, ensuring that the exhaust gas is in full contact with the catalyst.

5.7 The precious metal content test of the catalyst block shall be carried out according to the CCS accepted standard, and the test results shall be within 0.95~1.05 times of the manufacturer's design value.

5.8 When the ASC is installed in the engine using marine fuels, the catalyst shall be compatible with fuels with a certain sulfur content, and this capability shall be clearly specified.

5.9 The ASC reactor shall be of sufficient strength to withstand the effects of vibration on board.

5.10 The deterioration rate of ASC performance, such as the replacement conditions or replacement time of the catalyst block, shall be considered. The deterioration curve or catalyst life of the catalyst shall be obtained through testing or engineering application, or the deterioration resistance of the catalyst shall be verified through rapid aging test.

5.11 Performance requirements for the ASC

- (1) The NH_3 conversion efficiency test carried out in accordance with the standards accepted by the CCS shall meet the design requirements.
- (2) The NO_x selective conversion efficiency test carried out in accordance with the standards accepted by the CCS shall meet the design requirements.
- (3) The N_2O selective conversion efficiency test carried out in accordance with the standards accepted by the CCS shall meet the design requirements.
- (4) Other tests on the output of harmful pollutants carried out in accordance with the standards accepted by the CCS shall meet the design requirements.
- (5) Carry out the ASC sulfur resistance performance test and rapid aging test in accordance with the standards accepted by the CCS. After the test, the decrease of NH_3 conversion efficiency shall not exceed 20%, and the increase of $\text{NO}_x/\text{N}_2\text{O}$ selective conversion efficiency shall not exceed 10%. The replacement time shall meet the requirements of the Designer.
- (6) The ASC shall have sufficient NH_3 conversion capacity. Under steady-state engine operating

conditions, the ammonia concentration in the exhaust gas downstream of the reactor (i.e., ammonia slip) shall be limited. The conversion efficiency shall be no less than 90%. It is recommended that the design calculation basis does not exceed 110 ppm, and the limit values for potential harm to personnel shall also be considered. If conventions or regulations have specified emission limits for NH₃, N₂O, and other exhaust gas pollutants of the engine, these limit values shall serve as the basis for calculation.

5.12 The NO_x emission limit value of the engines with the ASC shall comply with the requirements of Clause 13.4 or 13.5.1.1 of MARPOL Annex VI. The leakage of NH₃ and N₂O in the exhaust gas pollutants of engines with the ASC shall be measured, and the emission limit value requirements of the conventions and regulations shall be met.

5.13 The design, manufacture and inspection of electronic equipment of the electronic control system, including software design, shall comply with Part 7 of the CCS Rules for Classification of Sea-going Steel Ships and the relevant provisions of the Guidelines for Type Approval Test of Electrical and Electronic Products. If it is arranged in conjunction with the SCR, the reactor electronic control system shall also meet the corresponding requirements of Chapter 4 of the Guidelines for Approval and Survey of Selective Catalytic Reduction (SCR) System.

5.14 The soot blowing device shall be able to realize automatic control operation. When the pressure difference before and after the reaction device exceeds the set value, it shall operate automatically, or the reasonable opening frequency and continuous working time shall be set to ensure reasonable pressure difference. The function of manual control shall also be provided for continuous soot blowing.

5.15 The monitoring function of the electronic control system shall be able to provide alarms for the main functional faults of the sensor, electronic control unit and actuator of the system.

5.16 The control unit of the ASC shall be able to effectively monitor the working status of key components (such as reaction device and soot blowing device), such as bypass status, inlet and outlet exhaust gas temperature of the device, inlet and outlet pressure difference, soot blowing system status/purging pressure, and control unit power faults/communication faults/sensor faults, and realize the function of interlocking/automatic control.

5.17 The ASC system shall have the functions of fault self-diagnosis and safety protection. When a fault occurs, the system shall immediately carry out fault diagnosis and activate the corresponding safety protection function.

5.18 The electronic control system shall have the function of data recording to automatically store abnormal states such as alarms and faults during the operation of the ASC system, and the storage records of abnormal states can only be cleared manually. The data shall be retained for not less than 18 months from the date of recording.

5.19 The auxiliary equipment of the ASC, such as bypass system and soot blowing device, shall meet the corresponding requirements of Clause 3.6 of the Guidelines for Approval and Survey of Selective Catalytic Reduction (SCR) System of CCS.

6 Materials and components

6.1 The main components of the ASC shall be provided with CCS Marine Product Certificate or Manufacturer certificate, and the relevant requirements of Chapter 3 of Part 1 of the Rules for

Classification of Sea-going Steel Ships of CCS shall be followed. The identification number (ID) or composition/type, structural form (such as CPSI) and manufacturer of the catalyst block shall be approved by CCS.

6.2 The materials used for the main parts and components of the ASC (shells, pipelines, valves, accessories) shall be suitable for the intended temperature, pressure and medium.

6.3 The copper, copper-containing alloys, zinc, zinc-containing alloys, cadmium- and mercury-containing materials and other materials susceptible to ammonia corrosion shall not be used for shells, pipelines, valves, accessories and other parts and components in contact with ammonia.

6.4 For the shells and pipeline systems made of carbon manganese steel or nickel steel, the influence of stress corrosion cracking caused by ammonia shall be minimized according to the selected material, design conditions and other factors.

6.5 When carbon manganese steel is used for shells and pipelines in contact with ammonia, fine-grained steel shall be used. The specified minimum yield strength shall not exceed 355 N/mm², and the actual yield strength shall not exceed 440 N/mm² (for example, carbon manganese steel with steel grades of CL-II-2 and CL-III-2 requiring post-welding stress relieving heat treatment). One of the following structural or operational measures shall also be taken:

- (1) Lower-strength materials with a specified minimum tensile strength of not exceeding 410 N/mm² shall be used;
- (2) Shells and other parts shall undergo heat treatment to eliminate stress after welding;

6.6 If carbon manganese steel with yield properties exceeding those specified in 6.5 is used, shells and pipelines shall undergo heat treatment to eliminate stress after welding.

6.7 The nickel steel containing more than 5% nickel and the carbon manganese steel that does not meet the requirements of 6.5 and 6.6 shall not be used for shells and pipeline systems in contact with ammonia.

6.8 Gaskets and seals shall be made of the metal, rubber, polymer and other materials compatible with ammonia (for example, spiral wound gaskets and PTFE).

7 Type test

7.1 General requirements

7.1.1 For the ASC of the same design but different specifications, if they are designed according to the principle of scaling, the whole series can be approved after selection of typical samples for the type test. For the principle of scaling, refer to Clause 7.2 of this chapter.

7.1.2 Before the type test for the ASC is carried out, it shall be confirmed that the series of drawings and technical documents within the scope of its approval (refer to the requirements of Clause 4 of the Guideline) have been approved by CCS.

7.2 Principle of scaling

7.2.1 The ASC designed based on the principle of equal scaling and applicable to different engine

exhaust gas flow rates (rated working condition) shall meet the following requirements:

- (1) The AV value, SV value and LV value of each system shall be consistent or meet the applicable range.
- (2) Catalysts used in each system: The composition/type, catalyst block structure and manufacturer shall be consistent.
- (3) The control strategy design rules of each system shall be consistent.

7.3 Selection of typical samples

7.3.1 For initial approval, one set of equipment shall be selected for the type test for each ASC series. The selected prototype shall be typical in terms of technical parameters, structure and manufacturing process, reflecting the processing capacity and manufacturing level of the factory.

7.3.2 For the ASC designed in conjunction with the SCR, it shall be considered in combination with the ASC system for Scheme A or to be used for both Scheme A and Scheme B at the same time. Its performance test shall be verified by engine + SCR + ASC according to the bench test of SCR Scheme A, or shall be verified in combination with the preliminary certification inspection of Scheme A.

7.3.3 The selection of engine + ASC for the performance test shall meet the following requirements:

- (1) The engine to be used for the test does not have to be the engine to be matched, and the ASC system can also be the equipment used for design and development.
- (2) The selection of engine + ASC for the test shall ensure that the space velocity of the ASC under the rated working condition of the engine is not less than the maximum space velocity applicable to the ASC.
- (3) If the selection of a corresponding engine as a prototype is not available due to the fixed size and limited conditions of the catalytic reactor, and calculations or model calculations can prove that the design of the ACS can meet the requirements of the applicable maximum space velocity and that there is a surplus volume of catalyst blocks, the requirements of Paragraph (2) above may be lowered.
- (4) Considering that catalyst blocks of the same manufacturer and model may have different CPSI, the designer will take AV consistency as an important design consideration, and the space velocity will be different. When selecting the performance test prototype, the maximum AV can be used as the selection parameter. However, this exception is only limited to the performance verification test and does not apply to other items listed in Table 7.4.

7.4 ASC type test items

The ASC applying for issuing the type approval certificate shall carry out the type test according to the items listed in Table 7.4 and submit the corresponding test report

Table 7.4 ASC Type Test Items

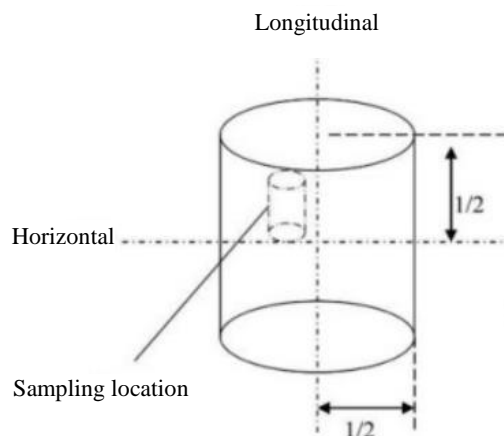
No.	Test items	Test requirements	Description	
1	Appearance and dimension inspection	Approved design drawings		
2	Tightness test	Approved design drawings		
3	Precious metal content of catalyst	5.7	Catalyst block	
4	Sulfur resistance test for catalyst	5.8, 5.11(1)~(3)	Sample can be used	
5	Vibration test for reactor or catalyst unit	5.9	Sample can be used	
6	ASC performance test	NH ₃ conversion efficiency test	5.11(1)	Sample
		Selective conversion efficiency test for NO _x	5.11(2)	Sample
		Selective conversion efficiency test for N ₂ O	5.11(3)	Sample
		Yield test for other harmful pollutants	5.11(4)	Sample
		Rapid aging test	5.11(5)	Sample
	Performance verification test	5.11(6), 5.12	Device	
7	Electronic control system test	5.13,5.15~5.18		
8	Functional test for auxiliary equipment	5.14, 5.19		
9	ASC technical dossier verification			

7.5 Test conditions and test sequence

7.5.1 Test conditions

- (1) The environmental conditions of the laboratory shall comply with the provisions of the recognized standards for the engine bench test.
- (2) The exhaust sampling and analysis system shall be able to measure the concentration of gas phase components such as NO_x, N₂O and NH₃. The gas analysis system shall meet the requirements of the 2008 NO_x Technical Regulations and/or equivalent standards.
- (3) Sampling method

Cut the ASC support from the longitudinal 1/2 and the transverse 1/2 respectively to obtain four parts - the upper left (lower) and upper right (lower) parts. Take any part and take a sample from the center of the support. The recommended sampling specification is $\Phi(20\sim25)\text{mm}\times(45\sim50)\text{mm}$. See Figure 1 for the schematic diagram of sampling. After sampling, purge and clean it with a compressed air. If the catalyst support is coated in zones, the sampling method shall be determined according to the coating process.

**Figure 1 Schematic Diagram of Sampling**

(4) Pretreatment

The sample shall undergo pretreatment. The thermocouple for measuring the inlet temperature shall be installed on the centerline near 25 mm upstream of the ASC inlet end face. Under the simulated atmosphere of exhaust composition, the inlet temperature is (550 ± 10) °C, the space velocity is (30000 ± 1500) h⁻¹, and the time is 1 h. After the pretreatment, close the reaction gas, introduce nitrogen, rapidly cool it down to be below 100 °C and maintain stable conditions. It shall be carried out according to the technical requirements of the catalyst manufacturer's pretreatment design.

7.5.2 Test sequence

3 sets of samples may be used for the test. The first set of samples shall be tested for the noble metal content. Another set of samples shall be sampled after appearance, size and tightness inspection, and the sample shall undergo pretreatment, fresh ASC performance test, rapid aging test and aged ASC performance test in turn. Another set shall be used for the vibration test.

7.6 Type test requirements

7.6.1 Appearance and dimension inspection

The outer surface of the ASC product shall be smooth and free of scratches; The welds shall be flat and free of cold solder joints and solder skips. The structure/interface dimensions of the reactor and its parts and components, the number of units and their arrangement within the reactor, as well as the thermal insulation protection, shall comply with the requirements of the approved design drawings.

7.6.2 Tightness test

The reactor assembly shall be tested for air tightness or equivalent tightness according to 1.1 times the design pressure or according to the factory design requirements (whichever is stricter), and the results shall meet the requirements of the approved design drawings.

7.6.3 Precious metal content of catalyst

According to different materials for the test sample supports, HJ 509 or QC/T 968 shall be selected for precious metal content testing, and the results shall meet the requirements of 5.7.

7.6.4 Sulfur resistance of catalyst

- (1) The manufacturer shall provide sufficient theoretical basis or experimental data support for the sulfur resistance of its catalyst.
- (2) The minimum and maximum operating temperatures of the catalyst applicable to fuels with different sulfur contents shall be provided.

The test shall be conducted based on the cumulative sulfur exposure determined by the applicable fuel sulfur content and catalyst replacement time.

For example: in case of 0.1% sulfur-containing fuel, 50% fuel utilization rate and 10000 h catalyst replacement time, the space velocity is (50000 ± 400) h⁻¹ during the test, the gas atmosphere is set according to Table 7.6.4, the sulfur poisoning time is 300 h at the 300 ± 5 °C

inlet temperature of the sample, and the cumulative sulfur exposure is 525 g/L. The conversion efficiency shall be measured according to the test conditions in Table 7.6.6, and the results shall meet the requirements of 5.11(5).

Table 7.6.4 Conditions for Sulfur Resistance Test

Component	SO ₂	H ₂ O	O ₂	N ₂
Concentration	25 ±5 ppm	(15 ±0.5)%	8~12%	Balance gas

7.6.5 Vibration test

- (1) Catalyst blocks or reaction device samples of appropriate size can be selected as vibration test samples according to the conditions of the vibration test bench.
- (2) The vibration test parameters shall be in accordance with Table 7.6.5.

Table 7.6.5 Vibration Test Parameters

On-board installation method	Frequency (Hz)	Amplitude (mm)	Acceleration (m/s ²)
With independent support or base	2 (+3/0)~13.2	±1.0	—
	13.2~100	—	±6.9 (0.7g)
Installed on the engine	2(+3/0)~25	±1.6	—
	25~100	—	±39 (4.0g)

(3) Test methods

- ① According to the frequency range and amplitude specified in Table 7.6.5, scanning shall be conducted at a frequency sweep rate of not exceeding 1 oct/min to check whether there is resonance;
- ② If there are no obvious resonance points, the vibration resistance test shall be carried out at 30Hz for 90min;
- ③ Perform the vibration resistance test for 90min at each recorded resonance frequency with an amplification $Q \geq 2$. If the measured resonance frequencies are close, the sweep frequency test can be adopted for the vibration resistance test, and the duration shall be 120min;
- ④ During the test, it is allowed to take measures to avoid dangerous frequency or reduce the Q value, but resonance inspection and vibration resistance testing shall be carried out again;
- ⑤ The test shall be carried out on 3 mutually perpendicular axes.

7.6.6 NH₃ conversion efficiency test

During the test, the space velocity is $(15000 \pm 400)h^{-1}$, and the gas atmosphere is set according to Table 7.6.6. The inlet temperature of the samples are 500°C, 450°C, 350°C, 300°C, and 275°C respectively, with a control accuracy of $\pm 5^\circ C$. The temperatures shall be measured one by one from high temperature to low temperature. The test conditions are shown in Table 7.6.6 (engine exhaust can also be used), and the results shall meet the requirements of 5.11(1).

Table 7.6.6 Performance Test Conditions

Component	NH ₃	O ₂	H ₂ O	CO ₂	N ₂
Concentration	10000 ±20 ppm	(10 ±0.5)%	(15 ±0.5)%	(5 ±0.5)%	Balance gas

7.6.7 Selective conversion efficiency test for NO_x/N₂O

The selective conversion efficiency test for NO_x/N₂O shall be conducted at different space velocities, temperatures and NH₃ concentrations according to the test conditions in 7.6.6, and the selective conversion efficiency of NO_x/N₂O at each temperature point shall be recorded. The results shall meet the requirements of 5.11(2) ~ (3). The conversion efficiency inflection point during the test shall be considered.

7.6.8 Yield test for other harmful pollutants

The selective conversion yield test for other harmful pollutants shall be conducted at different space velocities, temperatures and NH₃ concentrations according to the test conditions of 7.6.6, and the selective conversion rate of other harmful pollutants at each temperature point shall be recorded. The results shall meet the requirements of 5.11(4).

7.6.9 Rapid aging test

The rapid aging test utilizes samples for hydrothermal aging in a tube furnace or muffle furnace according to the accepted standard. The test conditions are shown in Table 7.6.9, and the results shall meet the requirements of 5.11(5).

Table 7.6.9 Rapid Aging Test Conditions

Inlet temperature (°C)	Space velocity (h ⁻¹)	Rapid aging time (h)
550±10	30000 ± 1500	100
(1): If hydrothermal aging is performed in an atmospheric muffle furnace, there is no requirement for space velocity.		

7.6.10 ASC performance verification test

(1) Verification of catalyst's ability to convert NH₃

- ① Verify the catalyst's conversion efficiency. For the engine equipped with the ASC according to Scheme A, at least 1 engine test cycle shall be selected, and the conversion efficiency of the catalyst at different space velocities, temperatures and NO_x concentrations shall be verified according to the NH₃ concentration, temperature and space velocity values under the test cycle conditions;
- ② The leakage of NH₃ and N₂O shall be measured, and the requirements of Clause 6.11 of the Guideline shall be met. The measurement of NO_x emissions shall meet the requirements of Clause 6.12 of the Guideline.

(2) Verification of rationality of control strategy (engine) design

- ① Spot check the operating conditions. On (or near, recommended deviation of approximately 5%) the engine propulsion characteristic curve (E3 cycle condition curve) or load characteristic curve (D2 cycle condition curve), at least one additional working condition (excluding the original mode point working condition of E3 or D2, and considering the original engine exhaust and ASC conversion efficiency characteristics) shall be selected, and the NH₃ conversion efficiency value plus 5% conversion efficiency under this working condition shall not be lower than the conversion efficiency interpolation of 2 nearby mode points in the cycle. If the verification test is combined with the preliminary certification inspection of Scheme A with the ASC, one working

condition shall be sampled on the curve of each test cycle to verify the conversion efficiency curve under the sampling working condition: consistency of space velocity-efficiency, temperature-efficiency and concentration-efficiency.

- ② The leakage of NH₃ and N₂O shall be measured and meet the requirements specified in Clause 6.11.6 of the Guideline.
- (3) Verification of the accuracy of modeling tool calculations and the rationality of scaling (applicable to Scheme B)
 - ① The accuracy verification of the scaling scheme and modeling tool of the applicant shall be completed before the on-board support in order to minimize the likelihood of initial inspection failure.
 - ② The applicant shall first submit the ASC scaling modeling tool, modeling calculation report and test report (if applicable) of the test prototype to verify the rationality of scaling and the accuracy of modeling calculation through tests.
 - ③ For the relevant requirements of ASC test and modeling tool, refer to MEPC.291(71).
 - ④ The leakage of NH₃ and N₂O shall be measured and meet the requirements specified in Clause 6.11.6 of the Guideline.
- (4) The verification test shall record at least the test data listed in Appendix 2.
- (5) For the performance test, refer to the test bench NO_x emission measurement procedure in Chapter 5 of NTC 2008.

7.6.11 Electronic control system test

The type test of the electronic control system shall be conducted in accordance with the relevant requirements of the Guidelines for Type Approval Test of Electrical and Electronic Products of CCS.

7.6.12 Function of auxiliary equipment

- (1) Functional test of the bypass system (if any) to verify the control and action of the bypass valve and indicator, interlock function, etc.
- (2) Functional test of soot blowing device (if any) to verify the control and action of the soot blowing system, soot blowing pressure and frequency, etc.

8 Unit/batch inspection

8.1 After obtaining the CCS type approval certificate, the ASC produced by the factory in accordance with the approval conditions may apply to CCS for single piece/single batch inspection.

8.2 The approved single piece/single batch inspection items shall meet the requirements of Table 3, and the corresponding test report shall be submitted after the inspection is completed;

Table 8.2 ASC Single Piece/Single Batch Items

No.	Test items	Test requirements
1	Appearance and dimension inspection	Clause 7.6.1 of the Guideline
2	Functional performance test	Check the version number and other information of the control software
3	Identification verification of emission-related parts and components	For emission-related parts and components, refer to Clause 9.2 of the Guideline
4	ASC technical dossier approval	1) Confirm whether the product is suitable for the intended engine. 2) Meet the requirements of Clause 9 of the Guideline.

8.3 Upon completion of the single piece/single batch inspection, CCS shall issue the marine product certificate and approve the ASC technical dossier.

9 ASC technical files and parameter check methods

9.1 ASC technical dossier

9.1.1 Each ASC shall be provided with a technical dossier, which shall at least include the following contents:

- (1) Specification of the catalyst block (and/or support) and its arrangement in the ASC. The detailed specifications of the catalyst block and the arrangement of the catalyst block in the ASC may include, but are not limited to:
 - ① Installation of catalyst block in ASC, including the quantity, layers and shell and frames of catalyst blocks to prevent waste gas leakage;
 - ② Geometrical dimensions of the catalyst block;
 - ③ Limiting features (e.g., CPSI) and ranges of physical parameters (such as SV, AV, LV), or part numbers or specification numbers designated by the applicant on the catalyst block;
 - ④ Materials of catalyst block: The materials can be identified by part number or specification number. Catalyst coating type, precious metal content and ratio shall also be included. Determine that the catalyst on board complies with the requirements in the technical dossier, and the method of specifying the part number or specification number by the applicant on the catalyst block shell or frame is acceptable;
 - ⑤ Arrangement of inspection ports. Inspection of the ASC is limited to ensuring the use of the correct catalyst block during the assembly stage. For inspections other than the initial assembly, it is acceptable to inspect the spare catalyst blocks to prove compliance;
- (2) Inlet parameters, including the allowable exhaust gas temperature (maximum and minimum) at the ASC inlet.
- (3) Cross-unit parameter: The allowable pressure loss (Δp) between the ASC inlet and outlet and across all components belonging to the ASC upstream and downstream of the reaction device.
- (4) Factors related to fuel quality that enable engines to continuously comply with applicable emission limit value may include, but are not limited to:

- ① Maximum allowable sulfur content of the fuel;
 - ② Description of fuel composition and fuel contaminants under operating conditions.
- (5) Factors related to ASC deterioration rate, such as replacement conditions and recommended replacement time of ASC catalyst block. Where applicable, the following requirements shall be considered:
- ① Equipped with NH₃ monitoring equipment, which can be accepted as a monitoring method for catalyst status/deterioration. The applicant shall clearly specify the correspondence between the replacement criteria of the catalyst block and the readings of the NH₃ monitoring equipment, and the maintenance, repair and calibration requirements of the NH₃ monitoring equipment;
 - ② If NH₃ monitoring equipment is not installed, the following description shall be provided:
 - Deterioration curve or catalyst life under normal operating conditions;
 - Parameters affecting the conversion efficiency of catalyst; and
 - Evaluate catalyst conversion efficiency based on the guidelines provided by the applicant for periodic inspection or monitoring (if applicable); records shall be kept for use during annual, intermediate, and renewal inspections. The periodic inspection frequency shall be determined by the applicant according to the deterioration of the catalyst, but shall be carried out at least once after installation and every 12 months thereafter; and
 - ③ Other strategies for monitoring catalyst status/deterioration should be submitted for approval.
- (6) Control mode and setting of ASC, such as model and specification of control equipment including but not limited to the following:
- ① Instructions on operation of sensors and components related to ASC control; (if applicable)
 - ② Instructions for crew on control parameters that allow adjustment, including protection against unauthorized changes to control parameters, PLC data and CPU; (if applicable)
 - ③ If NH₃ measuring device is used, the following descriptions shall be included as a minimum:
 - e.g. type/mode (identification number);
 - procedures for calibration, zero and full-scale checks and the periodicity of these checks, if applicable;
 - calibration gas equipped on board (if applicable);
 - maintenance and/or replacement requirements;
 - ④ If the engine system equipped with ASC has different operating modes, the control logic for selecting different modes shall be provided, along with records of operating modes and switching methods; and
- (7) ASC parameter check method (refer to Clause 9.2 of the Guideline).
- (8) Other parameters proposed by the applicant.
- (9) Technical dossier for certification of engine equipped with ASC shall also include:

- ① Information of engine family/group and information of member engines and their supporting ASC systems in the family/group;

9.2 ASC parameter check method

9.2.1 The parameter verification methods of the ASC system mainly include the following contents:

- (1) Verification of identification numbers of emission-related components (refer to Clause 9.2.2 of this chapter).
- (2) NH₃ measurement (for periodic inspection, refer to Clause 9.2.4 of this chapter).
- (3) Parameter logbook, used to record changes in emission-related components and setting values.

9.2.2 All emission-related components shall be marked with their identification numbers, and the location of these numbers on the components shall be clearly indicated in the technical dossier. Emission-related parts and components of ASC shall include but not be limited to the follows:

- (1) Catalyst block (and/or support).
- (2) NH₃ measuring device (control related).
- (3) Software version of ASC control system.

9.2.3 NH₃ measurement should include the following contents:

- (1) Periodic inspection (at least once after installation and every 12 months) or monitoring of the NH₃ concentration downstream of the ASC under each operating mode.
- (2) Provide evaluation criteria that allow for easy determination of whether the efficiency of the ASC remains consistent with that at the time of certification.

Appendix 1 List of Boundary Parameters of ASC

Parameter	Value
1. Catalyst	
Type	
Process (honeycomb, finned, or others)	
Main materials	
Mesh Size (CPSI of catalyst block)	
Manufacturer	
2. System parameters	
Maximum allowable pressure difference across the reaction device (at 100% load) kPa	
Applicable engine back pressure (at 100% load) kPa	
Applicable fuel quality and standards, and maximum fuel sulfur content (%)	
ASC system temperature, °C	
Catalyst block replacement cycle	
Applicable scaling range	
Applicable exhaust gas flow rate range (at 100% load) kg/h	
Applicable space velocity range 1/h	
Surface velocity m/h	
Linear velocity m/h	

Appendix 2 Verification Test Data Record Sheets

Mode		1	2	3	4	5	6	7	8
Power/Torque %									
Speed %									
Time at beginning of mode									
Environmental data									
Relative humidity %									
Ambient temperature °C									
Atmospheric pressure kPa									
Test condition parameter (f_a)									
Engine data									
Fuel mass flow kg/h									
Exhaust mass flow (q_{mew})									
Charge air coolant inlet temperature °C									
Charge air temperature °C									
Charge air reference temperature °C									
Charge air pressure kPa									
ASC data									
ASC inlet exhaust gas temperature, °C									
ASC outlet exhaust gas temperature, °C									
Exhaust gas pressure at ASC inlet, kPa									
Exhaust gas pressure at ASC outlet, kPa									
Pressure drop (ΔP) between ASC inlet and outlet, kPa									
Soot blowing pressure, kPa									
Emission data									
ASC inlet	NO _x concentration (dry/wet), ppm								
	NH ₃ concentration, ppm								
	N ₂ O concentration (dry/wet), ppm								
ASC outlet	NO _x concentration (dry/wet), ppm								
	N ₂ O concentration (dry/wet), ppm								
	O ₂ concentration (dry/wet), %								
	CO concentration (dry/wet), ppm								
	CO ₂ concentration (dry/wet) %								
	HC concentration (dry/wet) ppm								
	Ammonia leakage concentration ppm								
Other harmful pollutants ppm									