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Guielines for approval and survey of Selective Catalytic Reduction (SCR) system

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Preface

China Classification Society (CCS) is an authority for technical survey of ships in China and it is the only professional agency engaging in vessel classification survey business and a formal member of International Association of Classification Societies. China Classification Society provides technical specifications and standards and services including classification survey, certification survey, notarial survey, certification and accreditation service for vessels, offshore facilities and relevant industrial products according to relevant national regulations and international convention and rules and carry out statutory survey authorized by the government of China and governmental authorities of foreign countries (regions) and other businesses approved by relevant competent authorities.

These guidelines constitutes the CCS Rules, and establishes the applicable technical requirements and survey and test requirements of Selective Catalytic Reduction (SCR) system. It is a supplement to CCS Rules.

These guidelines is prepared and updated by CCS and issued on http://www.ccs.org.cn. The users of these guidelines are welcomed to give their feedbacks via ps@ccs.org.cn.

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Chapter 1 General

1.1 Application

1.1.1 These guidelines applies to Selective Catalytic Reduction (hereinafter referred to as SCR) system applying for the approval and survey of China Classification Society (hereinafter referred to as CCS).

1.1.2 These guidelines only applies to SCR system using aqueous urea as reductant. SCR system using ammonium hydroxide or liquid ammonia as reductant shall be approved with special consideration.

1.2 Normative reference

1.2.1 MEPC.198(62) *2011 Guidelines Addressing Additional Aspects to 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

1.2.2 IMO *International Convention for the Prevention of Pollution from Ships* (MARPOL) Supplementary VI

1.2.3 MEPC.177 (58) *NO_X Technical Code* revised by 251(66)

1.2.4 *Rules for Classification of Sea-Going Steel Ships* of China Classification Society

1.3 Purposes

1.3.1 The purpose of SCR system type approval is to prove that the product design conforms to the requirements of these guidelines and to facilitate the SCR equipment to realize the declared NO_X treatment capacity safely and continuously.

1.3.2 Principle and significance of SCR system type approval

(1) SCR system type approval is an approval to system security, function and purifying capacity. It does not include the pre-certification survey on matching diesel engine. Diesel engine fitted with SCR shall go through after-matching test according to Scheme A and B, so as to ensure that it can meet the requirement of pre-certification survey.

(2) The application of SCR system may bring unknown risks and type approval can guarantee the safety of newly-added equipment.

(3) SCR system type approval can be the early-stage preparation of emission test. After the performance of SCR reactor, on-board environmental suitability and possible modeling tools and model test are confirmed during the approval process, it can facilitate the classification of engine family/group fitted with SCR system and the selection of parent engine and the determination of system arrangement and control scheme, so as to reduce the pre-certification survey work for diesel engine fitted with SCR system.

(4) SCR system without CCS type approval shall be deemed as main component of diesel engine. During diesel engine pre-certification survey, plans and documents requested in Chapter 2 of these guidelines shall be submitted for approval and SCR system shall be surveyed according to the requirements for type approval in these guidelines, so as to ensure that the system conforms to the technical requirements in these guidelines.

1.4 Terms and definitions

1.4.1 Terms and definitions

(1) Selective Catalytic Reduction system: Selective catalytic reduction system is a system consisting of SCR chamber, reductant injection system, control device, exhaust pipe (if requested in design) and other necessary equipment.

(2) SCR chamber: It is also called catalytic converter. It is a complete device loading with catalyst block that can facilitate the reaction action between NO_X in exhaust gas and reductant to generate N_2 and H_2O. It is the core part of SCR system.

(3) Engine system fitted with SCR means a system consisting of a marine diesel engine, an SCR chamber and a reductant injection system. When a control device on NOx-reducing performance is provided, it is also regarded as a part of the system.

(4) Catalyst block means a block of certain dimension through which exhaust gas passes and which

contains catalyst composition on its inside surface to reduce NOx from exhaust gas.

(5) Reductant injection system means a system, which consists of the pump(s) to supply reductant to the nozzle(s), the nozzle(s) spraying reductant into the exhaust gas stream and control device(s) of the spray.

(6) SCR electrical control system means the system used to realize functions such as reductant injection control, system state monitoring and safety protection. It mainly consists of sensor, electronic control unit, actuator and external interface.

(7) SV (Space velocity) means a value of the exhaust gas flow rate passing through the catalyst block(s) (m^3 /h) per total volume of the catalyst block(s) in the SCR chamber (m^3). Therefore, unit of SV value is (1/h). The exhaust gas flow volume is the volume defined at 0°C and 101.3 kPa.

(8) AV (Area velocity) means a value of the exhaust gas flow rate passing through the catalyst blocks (m^3 /h) per total active surface area of the catalyst blocks in the SCR chamber (m^2). Therefore, unit of AV value is (m/h). The exhaust gas flow volume is the volume defined at 0°C and 101.3 kPa.

(9) LV (Linear velocity) means a value of the exhaust gas flow rate passing through the catalyst blocks (m^3 /h) per catalyst block's section (m^2) 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.

(10) Total volume of the catalyst block means the volume (m^3) based on outer dimensions of the catalyst block.

(11) Block section means the cross-sectional area (m^2) of the catalyst block based on the outer dimensions.

(12) NO_X reduction rate: means a value η (%) deriving from the following formula:

$$\eta = \frac{(C_{inlet} - C_{outlet})}{C_{inlet}} \times 100$$

Where: C_{inlet}—is NOx concentration (ppm) as measured at the inlet of the SCR chamber;

C_{outlet}—is NOx concentration (ppm) as measured at the outlet of the SCR chamber.

(13) Total active surface area: Total active surface area is the total surface area of catalyst block measured with selective chemisorption method.

(14) Reductant means urea solution that can be hydrolyzed to produce NH_3.

(15) Modeling tool: Modeling tool is a simulating calculation tool adopting diesel engine parameters and model test data to calculate the conversion efficiency of NO_X.

(16) Model test: Model test can provide data for modeling tool and it refers to the content in Class 6.1.1.3 of MEPC198 (62). It can be carried out with full-scale or scaled catalyst and the mixed gas can be diesel engine exhaust gas or simulated gas.

(17) Scheme A: It is a survey method to carry out bench test for diesel engine fitted with SCR system during pre-certification survey to prove the compliance of its emission.

(18) Scheme B: It is a survey method to prove the emission compliance of diesel engine through modeling calculation and initial confirmation test in case the emission compliance of diesel engine cannot be verified through bench test (refer to MEPC.198 (62)), or when on-board test cannot meet the requirements in Chapter 5 of NTC 2008 completely, the procedure in Scheme B of these guidelines shall be applied.

(19) Open-loop control: It is a system without feeding outlet parameter of SCR chamber (for example NO_X concentration at the outlet) back to influence the supply of reductant.

(20) Close-loop control: It is the control mode adopted to correct the reductant supply according to outlet parameter of SCR chamber (for example NO_X concentration at the outlet).

(21) Catalyst MSDS (Material Safety Data Sheet): It is a sheet containing physical and chemical parameters and hazardous information about the catalyst used for the user's reference and work safety.

1.5 Abbreviation and symbol description

1.5.1 Abbreviation and symbol description

(1) SCR: Selective Catalytic Reduction;

(2) SV: Space Velocity;

(3) CPSI: Channels Per Square Inch of catalyst cross section;

(4) PLC: Programmable Logic Controller;

(5) CPU: Central Processing Unit;

(6) $CO(NH_2)_2$: Urea;

(7) NH_3: Ammonia;

(8) ANR: Ammonia to NO_X Ratio.

(9) NTC 2008 (NO_X Technical Code 2008): NO_X Technical Code passed the resolution of the MEPC.177(58)

Chapter 2 Plans and Documents

2.1 Plans and documents submitted for approval

2.1.1 The following plans and documents shall be submitted for approval or for information:

(1) General layout of SCR system: It includes the installation and arrangement of components such as SCR chamber, bypass line, soot blower, mixer, nozzle, sensor (especially, control-related sensor), reductant supply pump. It shall also show the relative position of SCR system and diesel engine, for example, pre-turbo or post-turbo arrangement and exhaust branch or exhaust manifold arrangement, etc.

(2) Schematic diagram of SCR system

(3) Materials and specifications of main components including shell of reaction unit, soot blower, mixer, nozzle, metering pump and pipeline

(4) SCR chamber diagram

① SCR chamber structure diagram;

② SCR chamber shell structure strength calculation; (for information)

③ Installation and arrangement diagram of internal catalyst block, including quantity and arrangement of catalyst blocks and seal between catalyst block and SCR reactor shell to prevent exhaust gas leakage;

④ Structure diagram of catalyst block, including sizes and meshes (CPSI)

(5) Electrical control system, including system specification and software quality control plan; it shall be implemented according to the plans and documents requirements in Chapter 1, Part 7 of *Rules for Classification of Sea-Going Steel Ships* of China Classification Society. The serial number and version number of control software shall be stated explicitly in relevant documents.

(6) Reductant supply system

① Schematic diagram of reductant supply system

② Nozzle diagram, including model and specification, nozzle diameter, aperture number and spray-cone angle (for information)

(7) Drawings and documents of auxiliary equipment (for information)

① Bypass system structure diagram (if applicable);

② Soot blower diagram and gas consumption calculation sheet (if applicable);

③ Mixer structure diagram (if applicable);

④ Drawings of exhaust gas heating device and power calculation sheet (if applicable)

(8) Schematic diagram and explanation of SCR system control strategy;

① Control strategy flow chart and define the control mode (for example, open-loop or close-loop control);

② All input and feedback signals related to control

(9) Product main functional specifications:

① Performance Parameter Table, i.e. inlet and outlet boundary conditions and limits applicable to SCR chamber, including catalyst scaling range, exhaust gas flow range, AV and LV, NO_X concentration range, temperature range at the inlet of the chamber, pressure loss and other parameter ranges that may be applicable, such as ANR, SO_X, O_2, CO_2 and H_2O at least.

② Materials, composition/type of catalyst block;

③ Type/composition and concentration of reductant;

④ Applicable fuel quality, standard and maximum allowable sulphur content;

⑤ Factors related to SCR performance deterioration rate including catalyst block replacement condition and suggested replacement time.

⑥ Maximum conversion efficiency of catalyst (corresponding to different temperatures and AVs and ammonia-nitrogen ratio and ammonia slip amount shall be stated);

⑦ Explanation of the rationality of scaling scheme

(10) Uniform distribution calculation of exhaust gas flow field; the mixing of reductant and exhaust gas and the uniform distribution of ammonia gas (or ANR) when the fluid passing through the cross section of the chamber shall be considered; the uniformity shall not be lower than 85% (for information)

(11) Failure Modes and Effects Analysis (FMEA) (for information)

(12) Catalyst Material Safety Data Sheet (MSDS) and protective measures taken during catalyst block installation and replacement and waste recovery measures (for information)

(13) Type test program (it can be provided during type approval application)

(14) SCR technical files (refer to the requirements in 6.1 of these guidelines and can be provided during type approval application)

2.1.2 In Scheme B is planned to be used, at least the following documents and data shall be added for approval:

(1) Model test plan

(2) Instructions for modeling tools

(3) Model test report

(4) Modeling calculation report.

Chapter 3 Technical Requirements of SCR System

3.1 General requirements

3.1.1 Operating condition

(1) Designed operating condition of mechanical equipment shall meet the requirements on environmental condition in Section 2, Chapter 1, Part 3 of *Rules for Classification of Sea-Going Steel Ships* of China Classification Society.

(2) Designed operating condition of electrical equipment shall meet the requirements in Section 2, Chapter 1, Part 4 of *Rules for Classification of Sea-Going Steel Ships* of China Classification Society.

3.1.2 Piping system, valve and pipeline fittings shall meet relevant requirements Chapter 2, Part 3 of *Rules for Classification of Sea-Going Steel Ships* of China Classification Society.

3.1.3 The structural strength and designed pressure of SCR system installed in the upstream of turbocharger, its SCR chamber shell and all equipment (for example, the mixing device) and exhaust pipe in the upstream of the chamber shall be determined according to the design requirements of exhaust manifold of the matching diesel engine. Measures shall be taken to prevent the broken catalyst block from entering the supercharger.

3.1.4 Back pressure rising of SCR system during maximum exhaust gas flow shall meet the requirement of diesel engine manufacturer. When necessary, safety valve shall be installed on the exhaust gas line in the upstream of SCR chamber to prevent excessive exhaust gas accumulation due to excessive back pressure that may influence the normal work of diesel engine.

3.1.5 SCR system shall be able enough to reduce NO_X and the average concentration of NH_3 in the exhaust gas in the downstream of the chamber shall not exceed 10ppm under steady-state condition of diesel engine. If IMO has new requirements on this limit value, IMO requirements shall prevail.

3.1.6 In the case of an engine fitted with SCR system to be certified in accordance with paragraph 5.1.1 of regulation 13 in MARPOL Annex VI the specific emission at each individual mode point shall not exceed the applicable NOX emission limit value by more than 50% except as follows:

(1) The 10% mode point in the D2 test cycle

(2) The 10% mode point in the C1 test cycle

(3) The idle mode point in the C1 test cycle

3.2 Raw materials and parts

3.2.1 Main components of SCR system shall be supplied with certificate of products for marine service or certificate of manufacturer issued by the Society. Specific implementation shall be done according to relevant requirements in Appendix 2B, Chapter 3, Part 1 of *Rules for Classification of Sea-Going Steel Ships* of China Classification Society. It is not allowed to change manufacturer of catalyst block without the permission of the Society.

3.2.2 The materials used for equipment and parts of SCR system shall be applicable to its set temperature, pressure and media, especially structural components contacting with reductant, such as SCR chamber, mixer, soot blower, metering pump and supply pipeline.

3.3 SCR chamber

3.3.1 The design of SCR chamber shell shall meet the requirements in 3.1.3 and 3.2.

3.3.2 Measures (for example, lead sealing which shall have manufacturer logo on) shall be taken for SCR chamber to prevent catalyst block from being removed deliberately.

3.3.3 When sealing catalyst block in chamber, sealing measures shall be taken to prevent exhaust gas leakage to guarantee sufficient contact between exhaust and catalyst.

3.3.4 SCR chamber shall be in sufficient strength that can withstand the vibration onboard.

3.3.5 SCR system shall be able to adapt to certain sulphur (S) content of fuel oil and clear explanation shall be given.

3.3.6 Deterioration rate of SCR performance such as replacement condition or replacement time of catalyst block shall be considered.

(1) Since NO_X monitoring is adopted, the close-loop control SCR system is considered meeting the requirements in this Regulation.

(2) For open-loop control SCR system, the following instructions shall be provided or NO_X monitoring equipment shall be installed:

① Degradation curve and age of catalyst under normal operating condition;

② Parameters that have influence on the catalyst state;

③ Instructions for the evaluation of catalyst activity and state;

④ Instructions for the maintenance of catalyst

⑤ Periodical spot checks and record for operation survey and inspection.

3.3.7 The applicable exhaust gas temperature range for SCR chamber shall be stated and it shall be compatible with the test cycle adopted by the matching diesel engine.

3.4 Electrical control system

3.4.1 The design, manufacturing and survey, including software design, of electronic equipment in electrical control system shall conform to relevant stipulations in Part 7 of *Rules for Classification of Sea-Going Steel Ships* and *Guidelines for Type Approval Test of Electrical and Electronic Equipment*.

3.4.2 When making control plan for SCR electrical control system, actual operating condition of on-board engine shall be fully considered. When engine operating condition deviates from the characteristic curve (for example, propeller characteristic curve or constant-speed operation curve) normally, SCR system shall not stop reductant injection. The operating condition range of diesel engine involved in SCR system operation shall be covered in plane. It shall be designed according to the operating condition that may be reached during actual operation of diesel engine. However, the coverage area shall be no less than ±10% of the nominal characteristic curve. The actually measured NOx conversion efficiency value plus 5% shall not be lower than the conversion efficiency of designed operating condition (or curve).

3.4.3 The NOx conversion efficiency value under any operating condition on nominal characteristic curve plus 5% shall not be lower than the conversion efficiency interpolation at 2 cycle mode points near the operating condition.

3.4.4 The design of monitoring function and control function of electrical system for SCR system shall conform to relevant requirements in Chapter 4 of these guidelines.

3.5 Reductant supply system

3.5.1 Generally, reductant shall be ammonium hydroxide with a mass concentration of 32.5% or 40%.

3.5.2 The design of reductant supply system shall be able to guarantee the reductant atomization and injection pressure at the outlet of nozzle and that it is easy to check the injection pressure.

3.5.3 The metering pump shall have proper flow range which shall cover the flow range of reductant supply and guarantee sufficient precision of pump within that range.

3.5.4 After SCR system stops working, there will be reductant residual at the nozzle part. The evaporation or evaporation of the reductant may result in nozzle plugging. Reductant supply system shall have compressed air cleaning function or other equivalent measures to clean the residuals in nozzle after system stops working to prevent nozzle plugging.

3.5.5 For fluid supply pipeline, the maximum allowable relative height between metering pump and storage tank and nozzle and the maximum allowed length of fluid supply pipeline and other on-board installed requirements shall be stated to guarantee effective operation of system.

3.6 Auxiliary equipment

3.6.1 The exhaust pipe of diesel engine fitted with SCR diesel engine shall be equipped with bypass line and bypass state indicator to meet the following requirements:

(1) The valve on bypass line shall be able to be opened or closed manually or a set of power source shall be added to control the open and close of the valve.

(2) The design of bypass structure shall be able to prevent simultaneous close of SCR chamber channel and bypass line due to misoperation. One can be closed only when the other is opened.

(3) Interlocking function shall be activated to make the SCR system stop working and ensure that it cannot be initiated during bypassing.

(4) When a single diesel engine is used for main propulsion plant, bypass structure shall be set for its SCR system. When multiple diesel engines are used for main propulsion plant or auxiliary equipment, it is allowed not to set bypass structure for its SCR system.

3.6.2 Soot blower shall be set for SCR system to ensure that SCR chamber can work continuously and effectively to prevent the particulate matter (PM) in diesel engine exhaust gas from gathering on the catalyst surface and result in exhaust back pressure raise and system catalytic efficiency reduction. The following requirements shall be met:

(1) Sufficient blowing pressure and blowing frequency of soot blower shall be supplied to guarantee the active efficiency of the equipment;

(2) Gas consumption of soot blower shall be listed in the technical specifications;

(3) Blowing pressure and working state shall be monitored.

3.6.3 The design of SCR system shall ensure that the reductant and exhaust gas will be mixed fully before entering the chamber and the rationality of structural design will be verified through fluid simulating calculation. When the fluid passing the chamber section, the ammonia gas (or ANR) shall distribute uniformly and its uniformity shall not be lower than 85%. When necessary, mixer can be installed, but the requirements for the arrangement of exhaust gas pipeline before and behind the mixer including the requirement for the distance to the SCR chamber shall be stated.

3.6.4 The exhaust gas heating device installed to provide sufficient reaction temperature for SCR chamber shall meet the following requirements:

(1) When fuel oil is used to heat exhaust gas, gathering of combustible fuel gas and oil shall be avoided as much as possible during system design. When stop valve is installed on the fuel oil pipeline, its open-close state shall be indicated clearly.

(2) Regular pre-scavenging shall be carried out in gas flue before ignition of oil atomizer; the scavenging period shall be long enough to guarantee 4 times of furnace air change; air governing valve shall be opened fully during scavenging;

(3) Ignition shall be done before air entering the combustor and after pre-scavenging; filling valve of oil atomizer shall be opened after the appearance of ignition spark; if it cannot be ignited, the filling valve of ignition device and oil atomizer shall be closed automatically; the duration from opening and closing of filling valve shall be no longer than 15s;

(4) Flame monitor shall be installed, which allows the filling valve to be closed automatically in case of failure flameout; the time of close shall be no later than 6s after flameout;

(5) Within exhaust control area, the diesel engine shall be started up after scavenging.

(6) The fuel oil consumption of exhaust gas heating device shall not exceed 5% of the fuel consumption of the matching diesel engine under rated condition.

3.7 Redundancy

3.7.1 Electromechanical devices that may influence normal operation of SCR system due to functional fault in control system shall be equipped with dual system or onboard spare parts, for example, input signal sensor or electromechanical devices that may influence reductant metering control.

3.7.2 At least 2 reductant supply pumps shall be set for SCR system. Its configuration shall be able to realize: when 1 pump is in failure, the others can supply enough reductant under maximum operating condition of SCR system and all pumps shall be connected properly and shall be available or easy to be replaced at any time.

Chapter 4 Control, Monitoring and Safety Protection

4.1 General requirements

4.1.1 SCR electronic control system is to control reductant injection amount, SCR system operating state, bypass state and working state of soot blower and exhaust gas heating device (if any) and it can adjust SCR system parameter on the basis of the engine state to realize data exchange externally. SCR electronic control system consists of sensor, electronic control unit, actuator and external interface.

4.1.2 In addition to the requirements of this Chapter, the control, monitoring and safety system of SCR system also can meet relevant requirements in Chapter 3 of these guidelines.

4.1.3 SCR system shall have fault self-diagnosis and safety protection function; in case of fault, the system shall carry out fault diagnosis immediately and activate relevant safety protection function.

4.1.4 Electrical control system shall have data record function to record a certain amount of the latest operating data of SCR system and save the abnormal condition including alarming and fault during operation automatically. The storage record of abnormal condition can only be erased manually. The data shall be retained for at least 18 months since the date of record.

4.1.6 Data record and processing equipment of SCR system shall be able to output the system state, data and alarming to the monitoring system of the ship through external interface.

4.1.7 The sensor and monitoring equipment shall be guaranteed with reliability and accuracy and shall be calibrated regularly. Calibration procedure of the designer or the equipment supplier can be accepted.

4.2 Control

4.2.1 SCR system shall be able to realize automatic control operation and its reductant injection amount can be adjusted automatically according to the change of diesel engine operating condition, so as to guarantee the expected conversion efficiency and the minimum ammonia slip under different operating conditions.

4.2.2 Soot blower shall be able to realize automatic control operation. When the pressure difference before and behind the chamber exceeds the set value, it shall operate automatically, or proper start frequency and continuous working period shall be set to guarantee proper pressure difference. Besides, manual control function shall be set to facilitate continuous soot blowing.

4.2.3 Exhaust gas heating device shall be able to realize automatic control operation. The exhaust gas temperature corresponding to operation and stop shall conform to the technical document and the fuel oil supply shall be adjusted according to the change of temperature at the inlet of SCR chamber.

4.2.4 When the flame of exhaust gas heating device goes out, it shall stop fuel oil injection.

4.3 Monitoring

4.3.1 The monitoring function of electrical control system shall be able to realize main function fault alarm for the sensor, electronic control unit and actuator of the system.

4.3.2 In case of faults or failures, sensor that may influence normal operation of SCR system due to functional fault in control system, especially sensor that may influence reductant metering control shall be able to:

(1) Send alarm signal;

(2) Replace damaged parts or use backup equipment timely to get back to normal control function;

4.3.3 Control unit of SCR system shall be able to monitor the working state of key components including the reaction unit, reductant supply system, blowing device and exhaust gas heating device effectively. See detailed items in Regulation 4.5 List of Monitoring Items in this Chapter.

4.4 Safety equipment

4.4.1 In case of electromechanical device breakdown due to the action of safety system, alarm signal shall be sent and fault shall be indicated. The device is not allowed to be put into service automatically unless manual reset is made.

4.4.2 Interlocking mechanism shall be set to prevent simultaneous close of SCR chamber channel and bypass line due to misoperation. The bypass operation steps shall be: open the bypass valve completely

and then close the SCR chamber channel.

4.5 List of SCR system monitoring items

4.5.1 The SCR system monitoring items shall meet the requirements in Table 4.5.1.

4.5.2 The symbols adopted in Table 4.5.1 in this section and their meanings are shown below:

(1) —: Not required;

(2) X: Applicable;

(3) *: If any;

4.5.3 SCR systems adopting different control strategies have different monitoring items. Monitoring items shall be added according to system characteristics.

List of SCR System Monitoring Items Table 4.5.1

Item	Control Station (Room)		Classification of safety system action		Remarks
	Display	Limit alarm	SCR autostop	* Bypass	
1 SCR system working state					
SCR system work	Operation indication	—	—	—	
Bypass	State	Fail	—	—	
2 Chamber					
SCR chamber inlet & outlet pressure difference	Pressure difference	High	—	—	Soot blower works
		Extreme high	X	X	
3 Reductant supply system					
Reductant injection amount	Injection amount	—	—	—	
Supply pump fault	—	Fault	—	—	Start or replace stand by pump
Injection pressure	Pressure	Low	—	—	
Nozzle	—	Fault	—	—	
4 *Soot blower					
Soot blower system works	Operation indication	—	—	—	
Blowing pressure of soot blower	Pressure	Low	—	—	
5 * Exhaust gas heating device					
Exhaust gas heating device works	Operation indication	—	—	—	
Flame and ignition of heating device	—	Going out /fail	—	—	
Fuel oil pressure of heating device	Pressure	Low	—	—	
Power fault of burner blower	Voltage	Fault	—	—	Voltage can be replaced with indicator light
6 Control system					
Power fault of control unit	Voltage	Fault	—	—	Voltage can be replaced with indicator light
Communication fault of control system	—	Fault	X	X	
Main sensor fault (control-related)	—	Fault	X	X	

Chapter 5 Technical Requirements for SCR System Test

5.1 General requirements

5.1.1 For SCR systems in the same design but in different specifications, if it is designed based on scaling principle, the whole series can be approved after typical samples have been used for type test. Refer to Regulation 5.2 in this Chapter for scaling principle.

5.1.2 Before type test of SCR system, it should be confirmed that the plans and documents (according to the requirements in Chapter 2 of these guidelines) for the series within the range of approval has been approved by CCS.

5.2 Scaling principle

5.2.1 SCR system adopting scaling principle and applicable to different diesel engine exhaust gas flow rate (rated condition) shall meet the following requirements:

(1) AV, SV and LV values of different systems shall be the same or be in the range of application.

(2) Catalyst used for different systems: composition/type and catalyst block structural style shall be the same.

(3) Reductant used for different systems: composition/type and concentration shall be the same.

(4) Control strategy making rules of different systems shall be the same.

5.3 Selection of typical samples

5.3.1 During first approval, one set of equipment shall be selected for each series of SCR systems for type test. The sample selected is representative in terms of technical parameter, structure and manufacturing process and can embody the processing capability and manufacturing level of the factory.

5.3.2 The performance verification test for SCR system used in Scheme A or in both Scheme A and B shall be done by adopting diesel engine + SCR mode and bench mode in Scheme A or by combining pre-certification survey in diesel engine Scheme A.

5.3.3 The selection of diesel engine + SCR for verification test shall meet the following requirements:

(1) The selection of diesel engine + SCR for test shall ensure that the space velocity (SV) of SCR catalyst under rated condition of the diesel engine is no lower than the maximum space velocity applicable to the SCR system. Diesel engine for test does not have to be the proposed matching diesel engine and the SCR system can be the equipment for design development.

(2) When combining pre-certification survey in diesel engine Scheme A to carry out verification test, the test sample used shall meet the requirements in Regulation (1). However, it should be noticed that, for pre-certification survey in diesel engine Scheme A, the parent engine selected shall ensure that the diesel engine + SCR system has maximum NOX specific emission value in principle. If the matching unit or family of the approved SCR system has been stated, it can be exempted from the requirements in Regulation (1). It can be carried out by combining the parent engine test and the parameter range applicable to the SCR system shall be the parameter scope of the group or family. The approval of SCR system can be limited to the group or family of the diesel engine and it shall be stated in the certificate.

(3) If relevant diesel engine cannot be selected as sample due to the fixed size of catalyst block and condition restrictions and it can be proved through calculation or model calculation that the design of SCR system can meet the requirements of applicable maximum space velocity and the catalyst volume has allowance, the standard in this Regulation can be lowered.

5.4 SCR system type test

5.4.1 The items of type test shall be able to confirm that SCR system and its parts and components conform to the technical requirements in the approved drawings and Chapter 4 of these guidelines. Type test of SCR system includes the following content and conversion performance test specified in 5.4.2:

(1) The internal and external structure of SCR chamber and that in the approved drawings shall be the same and technical requirements in 3.3 shall be confirmed;

(2) The structure size and number of units of catalyst block and its arrangement in the chamber shall be inspected;

(3) Sulphur resistance of catalyst

① The manufacturer shall provide sufficient theoretical foundation of or test data on sulphur resistance of its catalyst as support.

② Provide minimum and maximum working temperature of catalyst applicable to fuel oil of sulphur content.

(4) Deterioration rate of catalyst

① Obtain degradation curve and catalyst age under common operating condition through test; or

② Rapid aging test. The degradation rate of NO_X conversion efficiency due to SCR aged rapidly shall not exceed 10%. Rapid aging test shall be done on test bench and test cycle is shown in Table 5.4.1(4).

③ Chamber for test can be connected with engine or burner based on test bench condition and proper size shall be selected.

Table 5.4.1(4) Rapid Aging Test Condition

Inlet temperature (℃)	Space velocity (h^{-1})	Duration of aging (h)
550	50,000	200

(5) SCR chamber vibration test

① Relevant method for vibration test in GB/T 18377 shall be used.

② Table 5.4.1(5) Parameters for Vibration Test

Table 5.4.1(5) Parameters for Vibration Test

Frequency (HZ)	Acceleration (m/s^2)
30	±4.0g

③ Due to structural difference of catalyst blocks (cylinder or cuboid), different package structures are needed. Different package modes shall be defined to be used in different vibration tests individually.

④ The chamber sample for test can be connected with engine or burner based on test bench condition and proper size shall be selected.

(6) The reductant storage tank, pump, nozzle and pipeline inspected shall conform to the technical requirements in the approved drawings and Chapter 4 of these guidelines;

(7) The auxiliary equipment inspected shall conform to the technical requirements in the approved drawings and Chapter 4 of these guidelines.

(8) Electrical control system test

① In addition to the relevant requirements in *Guidelines for Type Approval Test of Electrical and Electronic Equipment* of the Society, the electrical control system shall also meet relevant requirements in this Section.

② The function test and conversion performance test of electrical control system can be done simulatanously. During SCR system working verification, the reaction of electrical control system is in line with that expected and control parameters shall be verified.

③ The function tests such as safety protection and fault monitoring alarm shall be determiend according to relevant requirements in Chapter 4 or shall be carried out by combining the performance verificaction.

(9) Auxiliary equipment function test

① Functional verification of the following auxiliary equipment can be carried out by combining conversion performance verification test.

② Bypass system function test, to verify the control, action and interlock function of bypass valve and indicator.

③ Soot blower function test, to verify the control and action of soot blower system, as well as the soot

blowing pressure and frequency, etc.

④ Exhaust gas heating device (if any) function test, to verify the effectiveness of the device, so as to guarantee effective operation of SCR system under low-temperature condition.

5.4.2 SCR system performance verification test

(1) Verification test condition shall meet the requirements in 5.3.3 of this Chapter.

(2) Selection of mode point for verification test

① 4 operating points stipulated for diesel engine E3 or D2 cycle. If the verification test is carried out by combining the pre-certification survey (EIAPP certification survey) in engine Scheme A, its mode point shall include all cycles applicable to the diesel engine unit.

② Random point survey. One any other operating point (excluding the original mode points in E3 or D2) should be selected from diesel engine propeller characteristic curve (E3 cycle condition curve) or D2 cycle condition curve (or near, a deviation about 5% is suggested). The NOx conversion efficiency value under this point plus 5% shall not be lower than the conversion efficiency interpolation at 2 cycle mode points nearby during the cycle. If the verification test is carried out by combining pre-certification survey (EIAPP certification survey) in engine Scheme A, one operating condition shall be chosen for test on each curve of test cycle.

③ Verify the maximum conversion efficiency of catalyst. Select 2 diesel engine operating conditions to control SCR system manually or change the reductant injection amount under the operating condition temporarily. At this time, the reductant injection amount shall be determined according to the temperature and space velocity value under the operating condition on the basis of the corresponding ammonia-nitrogen ratio in 2.1.1(9) ⑥. Verify the maximum conversion efficiency of catalyst by comparing the measured NO_X conversion efficiency and ammonia slip with that in 2.1.1(9) ⑥. 1 operating condition can be the same to that selected in 5.4.2(2) ②.

(3) Test result

① Calculate the NO_X conversion efficiency at each operating condition point and the NO_X specific emission value in each test cycle;

② Measure the ammonia slip amount shall it shall conform to the requirements in 3.1.5 of these guidelines.

(4) During verification test, the test data in Appendix 2 shall be recorded at least.

(5) Performance verification test shall conform to the bench NO_X emission measurement procedure in Chapter 5 of NTC 2008.

5.4.3 For SCR system planned to be used in Scheme B, modeling calculation and model test shall be done before performance verification test. See the details in 5.6 and 5.7 of this Chapter and modeling calculation report shall be submitted before verification test. Verify the correctness of calculation value of each mode point in 5.4.2(2) ① on the basis of the verification test result.

5.5 Performance verification test principle

5.5.1 For SCR system planned to be used in Scheme B, the performance verification test shall be able to verify the effectiveness of modeling tool; in Scheme B, no matching test of diesel engine and SCR system shall be carried out on bench and the initial confirmation test onboard is a simplified validation mode. Therefore, the performance conversion verification test for SCR system planned to be used in Scheme B shall be done before getting on board and it shall not be equivalent to the initial confirmation test onboard.

5.5.2 For SCR system planned to be used in Scheme B, the performance verification test flow is shown in Fig. 5.5.2 and the specific steps are as follow:

(1) Obtain parameters including raw NOx emission of diesel engine;

(2) Provide data for modeling calculation through model test;

(3) Use modeling tools to calculate the conversion efficiency of SCR system;

(4) At last, use diesel engine bench to carry out performance verification test in 5.4.2.

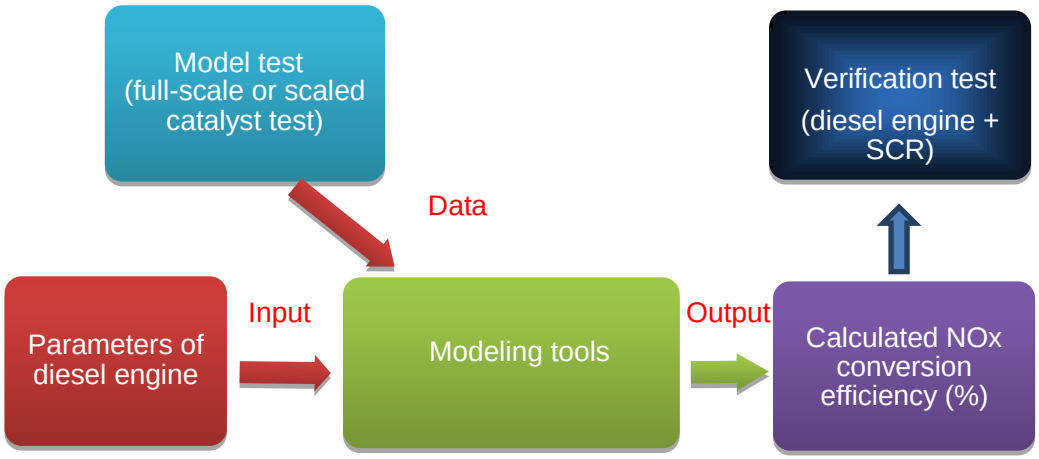


Fig. 5.5.2: Performance Verification Test Flow (SCR system used for Scheme B)

5.5.3 The performance verification test in Regulation 5.4.2 of these guidelines can be used to verify the following aspects of SCR system:

(1) The rationality of hardware design and control scheme of SCR system;

(2) Rationality verification of scaling scheme of the chamber (Verify the maximum space velocity value applicable to the SCR system);

(3) NO_X reduction ability of catalyst of SCR system;

(4) The ability of SCR system to ensure that the NO_X of diesel engine conforms to the emission limit;

(5) The correctness of calculation of modeling tool;

5.6 Modeling tools

5.6.1 Modeling tools shall have sufficient calculation ability and calculation accuracy. Its design principle, calculation method, input and output and constrains shall be stated in detail in the instructions for modeling tools and shall be embodied in calculation report.

5.6.2 Geometrical conditions, chemical reaction mechanism and modeling calculation method of other parameters shall be considered when using modeling tools to calculate the NO_X conversion efficiency and it shall be approved by the Society.

5.7 Model test

5.7.1 Model test is used to determine the performance and reaction efficiency of catalyst under different reaction condition, so as to provide necessary data input for the calculation of modeling tools. It can be carried out with full-scale or scaled catalyst and the mixed gas can be diesel engine exhaust gas or simulated gas. The test condition of modeling test:

(1) Exhaust flow; exhaust gas flow rate for the test should be scaled accordingly to account for the dimension of the catalyst model.

(2) Components of exhaust gas

① Exhaust gas for the test should either be diesel engine exhaust gas or simulated gas.simulated gas

② Exhaust gas for the test should either be diesel engine exhaust gas or simulated gas. Where diesel exhaust gas is used it should correspond, in terms of concentrations, to the exhaust gas in 5.5.2(1) of these guidelines, in terms of NOx, O_2, CO_2, H_2O, and SO_2 (±5% of the required concentration for each emission species).these guidelines

③ Where simulated gas is used it should correspond, in terms of concentrations, to the exhaust gas in 5.5.2(1) of these guidelines, in terms of NO, NO_2, O_2, CO_2, H_2O, and SO_2 (±5% of the required concentration for each emission species) balance N_2.

④ If the applicant can prove that the component and concentration of gas (or gases) mentioned above do not have any influence on the modeling calculation process, the relevant requirement on the concentration of relevant gas component can be ignored.

(3) Exhaust gas temperature; the temperature of exhaust gas used for the test should correspond to the temperatures obtained from testing in 5.5.2(1) of these guidelines, ensuring that the SCR chamber is activated at every load point, other than as provided for by 3.1.6 of these guidelines, and that no ammonia bisulphate formation, or reductant destruction, takes place.

(4) Catalyst blocks and AV, SV value; the catalyst blocks used in the test should be representative of the catalyst blocks to be used in the SCR chamber in service. AV, SV or LV value should, in the case of full scale tests, be within a range of ±20% of the required value as obtained in testing from 5.5.2(1) of these guidelines. In the case of scaled tests it should correspond to the above.

(5) Reductant; the reductant concentration should be representative of the reductant concentration in the exhaust gas during actual operation. For simulated gas, the reductant can be replaced with ammonia gas.

5.8 Survey on single piece/single batch

5.8.1 After obtaining the CCS type approval, the factory can apply to CCS for survey on single piece/single batch of SCR system manufactured under approved condition.

5.8.2 Survey on single piece/single batch after approval shall be done in accordance with the test items in 5.4.1(1), (2), (6) and (7) of these guidelines.

5.8.3 During the survey on single piece/single batch after approval, SCR technical file shall be reviewed and it shall be confirmed primarily that whether the product applies to the proposed diesel engine.

5.8.4 After survey on single piece/single batch, CCS shall sign and issue certificate of products for marine service or equivalent proof document and approve the SCR technical file.

5.9 Approval in Principle

5.9.1 Certification survey on SCR system approval in principle (AIP): This kind of survey is carried out to prove the rationality of the core of SCR system, i.e. the performance of catalyst and SCR system design and modeling tools. Even when the system is in concept design stage, if no complete product in kind can be produced for test or no diesel engine system is supplied for the verification of system performance, certification survey can be applied to the Society for approval in principle.

5.9.2 When apply for approval in principle to the Society, the content listed in Regulation 2.1.1(8), (9) and Regulation 2.1.2(1), (2), (3) of Chapter 2 of these guidelines shall be provided at least for approval. After being proved qualified, the approval in principle of the Society can be obtained.

5.9.3 Approval in principle cannot be used to replace type approval and type approval shall be supplemented and completed during product manufacturing stage. Plans and documents requested in Chapter 2 of these guidelines shall be submitted for approval and the SCR system shall be surveyed according to the type approval requirements in these guidelines. Type approval can be obtained after the system is proved to be qualified. Type approval principle in 1.3.2(4) can be referred to.

5.10 Certificate

5.10.1 After the SCR system is proved to be qualified in approval survey, relevant approval certificate shall be issued and SCR technical file shall be approved.

5.10.2 The range of application shall be specified in the approval certificate and product certificate of SCR system.

(1) SCR system applicable to Scheme A only shall specify that: “SCR system for this approval/survey only applies to diesel engines that adopting Scheme A to apply for pre-certification survey”.

(2) SCR system applicable to both Scheme A and Scheme B shall specify that: “SCR system for this approval/survey applies to diesel engines that adopting Scheme A and Scheme B to apply for pre-certification survey”.

5.10.3 The approval certificate and product certificate of SCR system shall include the content listed in “List of Boundary Working Parameters of SCR System” of Appendix 3.

Chapter 6 Typical File of SCR System and

6.1 Technical file of SCR system

6.1.1 One technical file shall be prepared for each SCR system and the technical file shall at least include the following content:

(1) Manufacturer and model of SCR system;

(2) Reductant: components/type and concentration;

(3) Reductant injection system, including key size, supply and model and specification of supply pump;

(4) Structural features of diesel engine exhaust manifold and specific SCR parts in SCR chamber exhaust pipe;

①The applicant shall suggest constrains related to structural design of exhaust pipe, including position and quantity of bend, direction and physical dimension of exhaust pipe and change and arrangement of pipe diagram;

②The distance from the position of reductant injection to SCR chamber;

③Position of nozzle and injection angle;

④Arrangement of mixer;

⑤Nozzle and atomization arrangement;

⑥The direction in which the exhaust entering the SCR chamber;

⑦Arrangement of bypass structure and valves;

(5) Specification of catalyst block and the arrangement of catalyst block in SCR chamber; at least includes:

①The installation of catalyst block, including the quantity and arrangement of catalyst block and sealing measures taken to prevent exhaust leakage, so as to guarantee sufficient contact between exhaust gas and catalyst;

②Physical dimension of catalyst block, including CPSI;

③Materials, components/type of catalyst which can be determined by defining the part number and identification number;

④Arrangement of soot blower;

⑤Arrangement of access hatch;

⑥Arrangement of baffle or similar devices;

(6) Cross-cell parameter: The allowable pressure loss (Δp) caused by all SCR system components between inlet and outlet of SCR chamber and in upstream and downstream of chamber.

(7) Fuel oil related factors that can guarantee that the diesel engine can be applicable to the NO_X emission limit continuously

①Maximum allowable sulphur content of fuel oil;

②Other restrictive components;

③Fuel oil pollutant that may cause poisoning of active materials during operation;

(8) Relevant factors that may influence the performance of SCR system, for example: condition for the replacement of SCR catalyst block and suggested accumulative work change time. For open-loop controlled SCR system, the following description shall be provided or NO_X monitoring equipment shall be installed:

① Degradation curve under normal operating condition;

② Age of catalyst under normal operating condition;

③ Parameters that may influence the state of catalyst;

④ Instructions for the evaluation of catalyst activity and state for periodical spot checks and record during operation survey;

⑤ Catalyst maintenance instruction for sailors;

(9) Control mode and setting of SCR system, for example: model and specification of control equipment, including but not limited to the following content:

① Document used to guide the sailors to adjust control parameters;

② Procedure for the zero check and full scale check of analyzer and periodic check; (if applicable)

③ On-board analyzer calibration gas (if applicable);

④ Reductant injection control strategy (referring to open-loop or close-loop control);

⑤ Instructions for the application of SCR control related sensor and components; (if applicable)

⑥ Introduction to the restriction on unauthorized rectification of configuration program and data of PLC and CPU system; (if applicable)

⑦ Data provided for gas analyzer, such as type/mode (identification number), calibration and zero and full scale checking program, onboard calibration gas, maintenance and/or replacement equipment;

⑧ Serial number and version number of control software;

⑨ If different control modes are designed for SCR system to ensure that the matching diesel engines conform to Tier II and Tier III respectively, control logical sum of different modes shall be selected and operation mode shall be recorded.

(10) Measures taken to reduce reductant leakage; specify measures to control ammonia slip and methods to be used to monitor ammonia slip during operation; adopt ammonia slip monitoring equipment; monitor the NO_X and control the parameter value.

(11) SCR system is applicable to boundary parameters

①Scaling range of SCR catalyst;

②Allowable temperature of exhaust gas at the inlet of SCR chamber (maximum and minimum);

③Applicable range of SV;

④Applicable range of NO_X emission concentration;

⑤Range of other applicable parameters, such as ANR, SO_X, O_2, CO_2 and H_2O

(12) SCR system is applicable to the schemes (Scheme A or/and Scheme B) and operating cycle of diesel engine.

(13) Modeling tool calculation sheet and model test report (applicable to Scheme B).

(14) Parameter check method of SCR system (referring to Section 6.2 of these guidelines)

6.2 SCR Parameter check method of SCR system

6.2.1 Parameter inspection method of SCR system mainly includes the following 4 aspects:

(1) Inspection of identification number of emission related components (see 6.2.2);

(2) Load related reductant mass flow rate inspection (see 6.2.3);

(3) NO_X measurement (periodical spot checks, see 6.2.4)

(4) Parameter record sheet is used to record the change emission related components and set value.

6.2.2 Component identification number of all emission related components shall be identified and the position of identification number on component shall be specified in technical files. Emission related parts and components of SCR system are:

(1) SCR chamber

(2) Catalyst block

(3) Mixing device

(4) Reductant nozzle

(5) Software version of SCR control system

6.2.3 Inspection of load related reductant mass flow rate mainly includes:

(1) Load related reductant mass flow rate of SCR system shall be monitored timely according to the requirements in Table 4.5.1.

(2) The reductant injection at each mode point shall be recorded regularly and compare it with that during pre-certification survey of diesel engine.

(3) The reductant filling volume, components and concentration onboard shall be recorded.

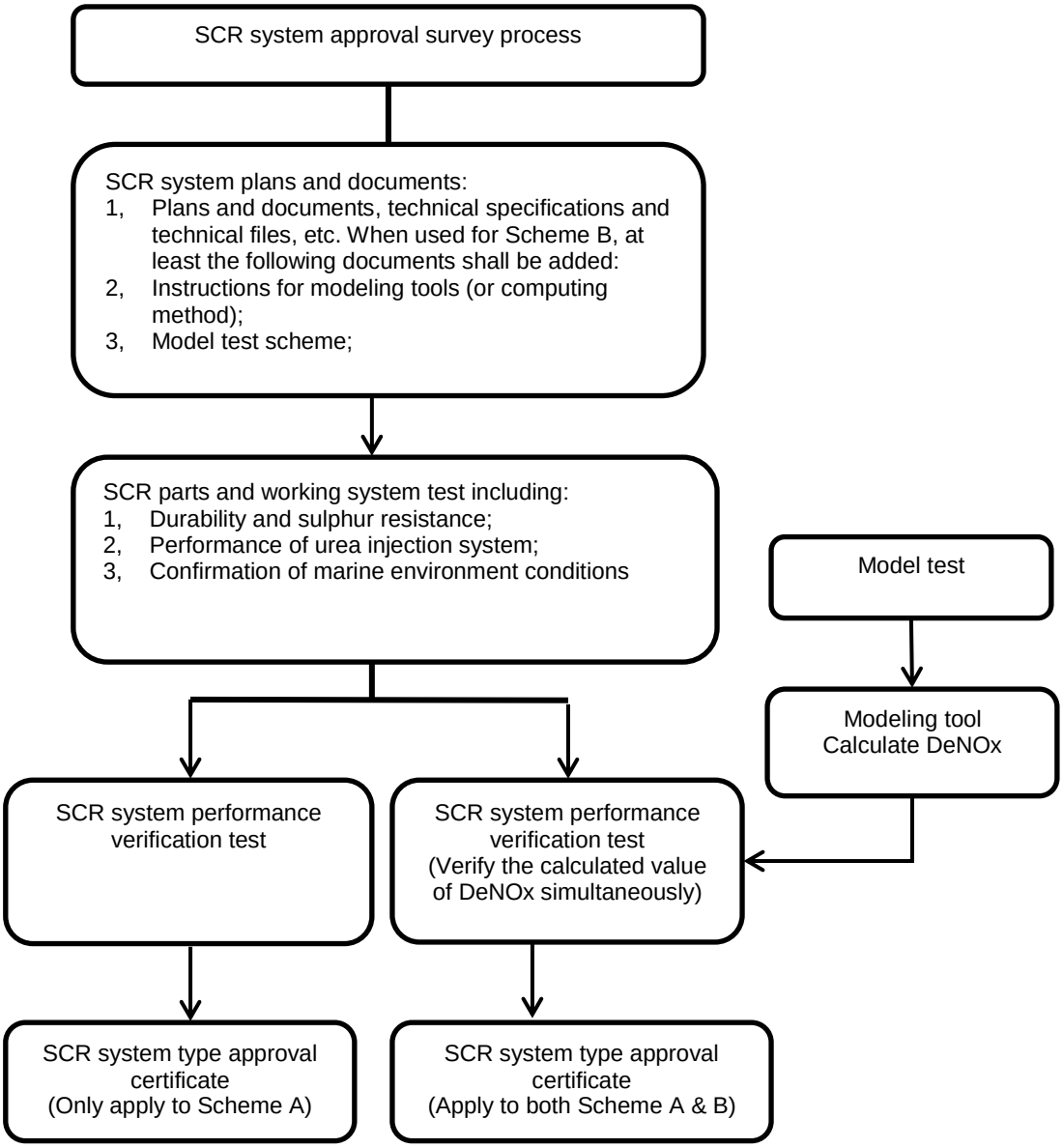
(4) The time and position of ECA-NO_X coming in and out from the ship shall be recorded;

(5) Total reductant consumption of SCR system shall be checked and recorded regularly and shall be compared with reductant filling volume.

(6) It is easy to determine whether the applicable purpose of NO_X limitation can be met through reductant consumption by providing judgment standard.

6.2.4 NO_X measurement is the periodical spot checksperiodical spot checks or monitoring on NO_X concentration at downstream of SCR. Record the NO_X inspection result at each mode point and compare it with the NO_X concentration at each mode points during first survey and certificate issuance of diesel engine. The statement above also applies to the inspection and monitoring of NH_3 slip.

Appendix 1 SCR System Approval Survey and Certification Process



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 ℃									
Atmospheric pressure kPa									
Test condition factor (fa)									
Engine data									
Fuel mass flow kg/h									
Exhaust mass flow (q_{mew}) kg/h									
Charge air coolant temperature in ℃									
Charge air temperature ℃									
Charge air reference temperature ℃									
Charge air pressure kPa									
SCR data									
Exhaust gas temperature SCR inlet ℃									
Exhaust gas temperature SCR outlet ℃									
Pressure SCR inlet kPa									
Pressure SCR outlet kPa									
Pressure drop over SCR (ΔP) kPa									
Reductant flow L/h									
Reductant inject pressure kPa									
Reductant concentration m/m %									
Soot blow pressure kPa									
Emission data									
SCR inlet	NO_X Concentration dry/wet ppm								
SCR outlet	NO_X Concentration dry/wet ppm								
	O_2 Concentration dry/wet %								
	CO Concentration dry/wet ppm								
	CO_2 Concentration dry/wet %								
	HC Concentration dry/wet ppm								
	NH_3 slip concentration ppm								

Appendix 3 List of Boundary Parameters for SCR System Working

Parameters	Values
Maximum allowable pressure different before and behind the chamber (100% operating condition) kPa	
Applicable diesel engine back pressure (100% operating condition) kPa	
Applicable fuel oil quality and standard, and maximum sulphur content in fuel oil %	
Beginning injection temperature of SCR system ℃, or beginning injection condition %	
Catalyst block replacement cycle	
Reductant concentration and specification %	
Minimum blowing pressure of soot blower kPa	
Minimum reductant injection pressure kPa	
Applicable scaling range of chamber	
Applicable exhaust gas flow range (100% operating condition) kg/h	
Applicable space velocity range 1/h	
Area velocity m/h	
Linear velocity m/h	
ANR application	