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K-08

Onboard Carbon Capture and Storage System

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Foreword

The product inspection guidelines of China Classification Society (hereinafter referred to as "CCS") have stipulated the applicable technical requirements and inspection and testing requirements for ship classification products and authorized statutory products that are intended to apply for CCS approval/inspection.

This guideline does not restrict users from using other testing methods and requirements, but the relevant testing methods and requirements shall not be lower than the requirements of this guideline.

These guidelines are written and updated by CCS through the website http://www.ccs.org.cn. Users can provide feedback on these guidelines to mp@ccs.org.cn if they have any opinions.

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Onboard Carbon Capture and Storage System

Chapter 1 General

1.1 Scope of Application

1.1.1 This guideline is applicable to Onboard Carbon Capture System (OCCS) applied for product review, approval, and inspection by China Classification Society (CCS) to reduce carbon dioxide emissions from combustion devices such as engines and boilers.

1.1.2 This guideline only applies to OCCS that adopts chemical absorption method and uses organic amine solution as absorbent. When other methods are adopted or in the case of combination with other systems, this guideline can be used as a reference, and its system shall be evaluated separately.

1.2 Normative References

1.2.1 CCS Rules for Classification of Sea-going Steel Ships

1.2.2 CCS Rules for Materials and Welding

1.2.3 Rules for the Construction and Equipment of Ships Carrying Liquefied Gases In Bulk

1.3 Terms and Definitions

1.3.1 Terms and Definitions

(1) Onboard Carbon Capture System (OCCS): refers to a system that captures gaseous carbon dioxide from the exhaust gas of a vessel’s combustion device and ultimately liquefies and stores it in a storage tank. It is generally composed of a carbon dioxide absorption unit, a carbon dioxide desorption unit, a carbon dioxide compression unit, a carbon dioxide liquefaction storage unit, an auxiliary unit, an electronic control system, pumps, valves, and auxiliary pipeline systems, as well as other necessary equipment.

(2) Carbon dioxide absorption unit: refers to a system that selectively captures carbon dioxide from the exhaust gas by spraying an organic amine solution into the exhaust gas. It is generally composed of exhaust gas cooling device, carbon dioxide absorption device, nozzle, filler, additional pipelines, etc.

(3) Carbon dioxide desorption unit: refers to the unit that releases gaseous carbon dioxide by spraying an organic amine solution rich in carbon dioxide into a desorption device and contacting a high-temperature medium for heat exchange. It is generally composed of desorption device, reboiler, a nozzle, filler, and additional pipelines.

(4) Carbon dioxide compression unit: refers to the unit that compresses gaseous carbon dioxide to a certain pressure, which is generally composed of carbon dioxide compressor, gas-liquid separator, heat exchanger, and additional pipelines and other components.

(5) Carbon dioxide liquefaction storage unit: refers to the equipment that liquefies gas carbon dioxide through a combination of the refrigeration compressor, the heat exchanger (condenser), and other components.

(6) Auxiliary unit: refers to the necessary related auxiliary equipment to ensure the normal operation of OCCS.

(7) Electronic control system: refers to a system that realizes such functions as system control, system status monitoring, safety protection, etc., which is generally composed of sensors, control units, actuators, and external interfaces.

(8) Exhaust gas cooling device: refers to the process of cooling exhaust gas in a carbon dioxide absorption device through pre-washing or heat exchanger to meet the temperature requirements of system operation.

(9) Reboiler: refers to the component used to heat an organic amine solution to reach its desorption temperature.

(10) Organic amine supply unit: refers to the unit that supplies organic amine solution to the absorption unit, which generally consists of organic amine solution storage tank, organic amine solution pump,

etc.

(11) Organic amine treatment unit: refers to a pry block unit that removes particles and other impurities from organic amine solution through filtration and other means. It is generally composed of circulating liquid treatment pump, membrane components, acid and alkali storage tanks, control systems, etc.

(12) Organic amine solution storage tank: refers to a storage tank used to store liquid amine solutions, including amine carbonate storage tanks formed for storage or temporary storage in carbon dioxide absorption units.

(13) Gas-liquid separator: refers to the equipment used to separate and remove liquids from carbon dioxide gas.

(14) Carbon dioxide storage unit: refers to a pressure vessel installed onboard to store liquid carbon dioxide.

(15) Triple point: refers to a set of temperature and pressure values in thermodynamics that allow the three phases (gas, liquid, solid) of a substance to reach thermodynamic equilibrium coexistence.

(16) System absorption capacity: refers to the ratio of the difference in carbon dioxide concentration before and after the exhaust gas passes through the carbon dioxide absorption device at rated load to the carbon dioxide concentration before and after passing through the absorption device.

(17) Capture energy consumption: refers to the energy consumption required by the system to capture and store 1t liquid carbon dioxide, usually expressed in GJ/t CO_2.

(18) Organic amine: refers to an alkaline compound in which one or more hydrogen atoms on ammonia are replaced by alkyl or aryl groups, mainly including alcohol amines, amides, fatty amines, aromatic amines, etc.

(19) Chemical absorption method: refers to a type of method that absorbs carbon dioxide in the form of a chemical reaction through a

chemical absorbent and desorbs carbon dioxide in the form of a chemical reaction under specific conditions.

Chapter 2 Drawings and Data

2.1 Plans and documents

2.1.1 The following drawings and data shall be submitted for approval or information:

(1) OCCS general layout, including the installation and layout of such components as carbon dioxide absorption unit, carbon dioxide desorption unit, carbon dioxide compression unit, carbon dioxide liquefaction storage unit, auxiliary unit, electronic control system, pumps, valves, auxiliary pipeline system, etc.

(2) OCCS schematic diagram (including the systems for carbon dioxide absorption, desorption, compression, liquefaction storage, etc.).

(3) Specification table of main components, including exhaust cooling device (if any), exhaust fan, absorption device, desorption device, reboiler, organic amine supply pump and pipelines, carbon dioxide heat exchanger, carbon dioxide gas-liquid separator, carbon dioxide compressor unit, carbon dioxide refrigeration unit, liquid carbon dioxide pump, carbon dioxide storage tank, etc.

(4) Structure diagram of exhaust gas cooling device (if any).

(5) Structure diagram of absorption device.

(6) Structure diagram of desorption device/reboiler.

(7) General diagram of carbon dioxide storage tank.

(8) The electronic control system, including system manual, software quality control plan, etc., shall be subject to the drawings and data requirements of Chapter 1 and Chapter 2 of Part 7 of the “Rules for Classification of Sea-going Steel Ships”. The model and version number of the control software shall be clearly stated in relevant documents.

(9) Auxiliary equipment drawings and documents (including organic

amine supply unit, organic amine solution treatment unit, etc.) (for information)

(10) OCCS control strategy manual, at least including:

① Control strategy flowchart, with clear control modes and strategies;

② All related input and feedback signals related to control.

(11) Main performance specifications of product:

① Performance parameters table, generally consisting of four parts, the absorption section: max. exhaust gas flow rate, max. gas-liquid ratio, pressure loss, and energy consumption; desorption section: desorption temperature, desorption pressure, purity of desorption carbon dioxide, and energy consumption; compression section: compression ratio, compression stage, vibration noise, energy consumption; liquefaction storage section: liquefaction temperature, storage pressure, storage temperature, energy consumption.

② Type/composition and concentration of organic amine solution;

③ Applicable exhaust gas components, such as concentration range of CO2, NOx, SOx;

④ Factors related to the degradation rate of organic amine solution performance, such as the replacement conditions and recommended replacement time of organic amine solution, etc.;

⑤ Max. absorption capacity;

⑥ Capture energy consumption.

(12) Failure mode and effect analysis (FMEA). (for information)

(13) Organic amine Material Safety Data Sheet (MSDS), protective measures to be taken during use and replacement, and waste recycling measures. (for information)

(14) Type test outline (can be provided when applying for approval)

(15) OCCS Technical Manual (refer to the requirements of Chapter 3 of this guideline)

(16) OCCS energy consumption calculation sheet (for information)

(17) OCCS processing capacity calculation sheet (forinformation)

Chapter 3 Technical Requirements for OCCS Approval

3.1 General Requirements

3.1.1 Working Conditions

(1) The design working conditions of mechanical equipment shall comply with the environmental conditions of Section 2, Chapter 1, Part 3 of the CCS “Rules for Classification of Sea-going Steel Ships”.

(2) The design working conditions of electrical equipment shall comply with the requirements of Section 2, Chapter 1, Part 4 of the CCS “Rules for Classification of Sea-going Steel Ships”. The electronic control system shall also meet the requirements of Chapter 2, Part 7 of the CCS “Rules for Classification of Sea-going Steel Ships”.

3.1.2 The piping, valves, and pipeline accessories shall meet the relevant requirements of Chapter 2, Part 3 of the CCS “Rules for Classification of Sea-going Steel Ships”.

3.1.3 The pressure vessels and heat exchangers used in OCCS shall meet the relevant requirements of Chapter 6, Part 3 of the CCS “Rules for Classification of Sea-going Steel Ships”.

3.1.4 The mechanical properties, chemical composition, manufacturing, testing, etc. of materials used in OCCS equipment and pipelines shall comply with the relevant provisions of CCS “Rules for Materials and Welding”, anti-corrosion measures shall be considered (when applicable), and the materials used shall be suitable for the medium. The materials (including coatings) used for equipment, pipelines, and components in contact with seawater shall be harmless to marine organisms. The pipelines shall be able to withstand the most severe combination of pressure, temperature, and other loads that may be encountered in the working environment.

3.1.5 The pressure loss generated by OCCS at maximum exhaust gas flow rate shall meet the requirements of combustion devices such as engines and boilers.

3.1.6 Organic amine solutions in OCCS are strictly prohibited from being directly discharged into the sea in any way.

3.1.7 Any equipment used or used for handling organic amine solutions in OCCS shall be provided with drip trays, which shall be equipped with drain pipes leading to appropriate storage tanks. The drain pipes can be equipped with organic amine leakage tanks or directly overflow to organic amine residue tanks.

3.1.8 When the exhaust gas cooling device in OCCS is cooled by spray washing, the washing water shall be discharged according to the requirements of IMO MEPC.340 (77) or MEPC 307 (73). If the ships burning high sulfur oil fuel use desulfurization systems as exhaust gas cooling devices, the washing water shall meet the requirements of IMO MEPC.340 (77); if the ship is not equipped with a desulfurization system, its exhaust gas cooling device is only used for cooling, and its washing water shall meet the requirements of IMO MEPC.307 (73).

3.1.9 If OCCS has the faults described in 4.4.3, the bypass valve shall be opened and the connection shall be cut off in a timely manner to avoid affecting the normal operation of such combustion devices as engines and boilers.

3.2 Raw Materials and Components

3.2.1 The main components of OCCS include exhaust gas cooling device (if any), exhaust gas fan, absorption device, desorption device, reboiler, organic amine supply pump and pipelines, carbon dioxide heat exchanger, carbon dioxide gas-liquid separator, carbon dioxide compressor unit, carbon dioxide refrigeration unit, liquid carbon dioxide pump, carbon dioxide storage tank, etc.

3.2.2 The materials for OCCS shall be selected with consideration to the ductility, corrosion resistance, and the possibility of hazardous reactions under operating temperature and pressure.

3.2.3 The organic amine solution storage tanks, pipelines, and accessories used for transporting undiluted solutions shall be made of steel with a melting point exceeding 925℃ or other equivalent materials.

3.2.4 The amine solution storage tank and related piping systems shall be made of materials compatible with the solution used, or appropriate anti-corrosion measures shall be taken.

3.2.5 The equipment and components of OCCS shall have corresponding certificates in accordance with the requirements of Appendix 2 of this guideline.

3.3 Absorption Device

3.3.1 The design and manufacturing of the absorption device shell shall meet the applicable requirements of 3.1 and 3.2.

3.3.2 The absorption device shell shall have good durability and corrosion resistance to ensure long-term reliable operation.

3.3.3 The filler, mist eliminator, nozzle pressure, and atomization particle size inside the absorption device shall meet the use requirements.

3.3.4 The absorption device shall be equipped with a liquid level monitoring device to provide timely alarm and shutdown signals.

3.3.5 The absorption device shall be able to withstand the loads that may be encountered under the design conditions of the vessel, including the dynamic loads generated by the vessel’s sway.

3.3.6 The exhaust gas temperature range applicable to the absorption device shall be clearly defined.

3.3.7 It shall be ensured that the pressure loss and applicable temperature of the absorption device do not exceed the specified allowable values.

3.4 Desorption Device

3.4.1 The design and manufacturing of the desorption device shell shall meet the requirements of 3.1 and 3.2.

3.4.2 The desorption device shell shall have good durability and corrosion resistance to ensure long-term reliable operation.

3.4.3 There shall be safety measures to prevent the risks caused by high temperature and pressure in the desorption device, as well as the impact on operators and the environment during equipment operation and maintenance.

3.4.4 The desorption device shall be equipped with a liquid level detection device to monitor the equipment liquid level and provide timely alarm and shutdown signals.

3.4.5 The desorption device shall be able to withstand the loads that may be encountered under the design conditions of the vessel, including the dynamic loads generated by the vessel's sway.

3.4.6 The temperature range and pressure range applicable to the desorption device shall be clearly defined.

3.5 Carbon Dioxide Compression Unit

3.5.1 The gas compressor shall be equipped with monitoring systems, alarm systems, and safety devices.

3.5.2 The carbon dioxide compressor shall have local and remote as well as emergency stop operations.

3.5.3 An overflow valve or overpressure protection device shall be installed on the discharge port of the carbon dioxide compressor.

3.5.4 A pressure gauge shall be installed on the exhaust side of the carbon dioxide compressor to monitor the exhaust pressure.

3.6 Carbon Dioxide Liquefaction Storage Unit

3.6.1 The control system, safety system, and alarm system of the carbon dioxide liquefaction storage system shall comply with the provisions of this chapter and Part 7 of the "Rules for Classification of Sea-going Steel Ships".

3.6.2 Materials of carbon dioxide liquefaction storage unit: the selection of materials, test methods, and related pipeline systems used in carbon dioxide storage systems shall comply with the provisions of the "Rules for Classification of Sea-going Steel Ships" and the "Rules for the Construction and Equipment of Ships Carrying Liquefied Gases In Bulk", with consideration to the minimum design temperature.

3.6.3 Carbon dioxide storage tank

(1) The design of carbon dioxide storage tanks shall meet the applicable requirements of Chapter 6 "Boilers and Pressure Vessels" in Part 3 of the "Rules for Classification of Sea-going Steel Ships" and Appendix 2 of Chapter A4 of Part 2 of the "Rules for the Construction and Equipment of Ships Carrying Liquefied Gases In Bulk" (hereinafter

referred to as the “Bulk Liquid Code”). For independent C-type dual /or triple tanks, the applicable requirements of Appendix 3, Section 5 shall also be met.

(2) The design of carbon dioxide storage, decompression, control, and monitoring systems shall consider the form, moisture content, and expected impurities of liquid carbon dioxide. In addition, the influence of impurities on the “triple point” temperature and pressure of carbon dioxide shall also be considered.

(3) If carbon dioxide is stored in a low-temperature insulated tank, the design party shall determine the pressure holding time.

(4) The inlet and outlet pipelines of carbon dioxide storage tank shall be equipped with remote and nearby shut-off valves, and a discharge port shall be set to discharge the condensate water that may be generated in the tank. A shut-off valve shall be installed on the discharging pipelines.

(5) The tank shall be equipped with access holes for personnel to enter the tank for inspection and maintenance.

(6) The tank shall be equipped with a drainage outlet to discharge the residues inside the tank.

3.6.4 Pressure relief system for carbon dioxide storage tanks

All carbon dioxide storage tanks shall be equipped with a pressure relief system that matches their design.

3.6.5 Measuring instruments and monitoring equipment for carbon dioxide storage tanks

(1) Each carbon dioxide storage tank shall be equipped with the instruments indicating the level, pressure, and temperature of carbon dioxide.

(2) Each carbon dioxide storage tank shall be equipped with at least two devices to indicate temperature, with one located at the bottom of the carbon dioxide storage tank and the other near the top of the tank, below the maximum allowable liquid level. The minimum temperature

designed for carbon dioxide storage tanks shall be clearly indicated by the signs on or near the temperature indicating device.

(3) If the storage and unloading of carbon dioxide are achieved through remote control valves and pumps, all controls and indicators related to the given carbon dioxide storage tank must be set in the same control position.

(4) Each carbon dioxide storage tank shall be equipped with a liquid level measuring device to ensure that the liquid level readings can always be obtained during operation of the carbon dioxide storage tank.

(5) Each carbon dioxide storage tank shall be equipped with a high level alarm device that operates independently of any level indicator and emits an audible and visual warning when being activated. However, installation is not necessary when the storage tank meets the following conditions:

① The volume of the storage tank does not exceed 200m^3; or

② The maximum pressure that may be withstood during loading operation is lower than the opening pressure of the carbon dioxide storage tank safety valve.

(6) Each carbon dioxide storage tank shall be equipped with a release valve to regulate the pressure for the purpose of automatic control.

(7) Each carbon dioxide storage tank shall be equipped with a high pressure alarm device.

(8) If the carbon dioxide storage tank is located in a enclosed space, the space used for the carbon dioxide storage tank needs to continuously monitor the accumulation of carbon dioxide. It shall be equipped with the monitoring of CO_2 concentration and O_2 concentration.

3.7 Electronic Control System

3.7.1 The design, manufacturing, and inspection of electronic equipment for the electronic control system, including software design, shall comply with the relevant provisions of Part 7 of the CCS “Rules for Classification of Sea-going Steel Ships”

and the “Guidelines for Type Approval Test of Electric and Electronic Products”.

3.7.2 The control scheme of the OCCS electronic control system shall fully consider the actual operating conditions of such combustion devices as onboard engines and boilers.

3.7.3 The monitoring and control functions of the electronic control system for OCCS shall be designed to meet the relevant requirements of Chapter 4 of this guideline.

3.8 Auxiliary Equipment

3.8.1 OCCS shall have a bypass structure. The bypass structure shall at least include the bypass pipeline, valve components, and bypass status indicator of the exhaust pipe, and meet the following requirements:

(1) The valves on the bypass pipeline shall be manually opened and closed locally, or an independent power source shall be added to control its opening and closing.

(2) The design of the bypass structure shall prevent the simultaneous closure of the OCCS absorption device channel and bypass pipeline due to misoperation. It shall be possible to turn on one path before closing the other one.

(3) When bypassing, there shall be an interlocking function to keep the OCCS stopped.

3.8.2 If OCCS uses an induced draft fan to extract some of the exhaust gas from the main exhaust gas pipeline for decarbonization, there is no need to set up a bypass mechanism.

3.8.3 Adequate measures shall be taken to prevent the reverse flow of waste gas cooling water and organic amine solutions from the waste gas cooling device and carbon dioxide absorption device back to the vessel’s combustion device, such as engines, boilers, etc.

3.8.4 Organic amine supply unit

(1) The capacity of the organic amine storage tank shall be meet the consumption of organic amines required by OCCS.

(2) The design of the organic amine circulation tank shall meet the solution storage capacity for the normal operation of the circulating liquid in the entire OCCS, equipment, and pipelines.

(3) As for the design of the organic amine supply unit, if spraying is adopted, it shall ensure the injection pressure at the nozzle outlet, and the injection pressure shall be easy to monitor.

(4) The supply pump shall have a suitable flow range, covering the flow and pressure range of the organic amine solution supply. A flow meter shall be installed in the spray main pipeline to facilitate flow adjustment of the organic amine solution according to the required amount of waste gas treatment.

(5) The maximum allowable relative height between the supply pump, storage tank, and nozzle, as well as the maximum allowable length of each section of the supply pipeline, and other onboard installation requirements shall be clearly defined to ensure effective operation of the system.

(6) Drip trays shall be installed at locations where leaks may occur in the absorbent storage tank and absorbent supply pipeline. The drip trays shall be equipped with a discharge device and an alarm device to discharge the absorbent into the overflow tank or other suitable tanks, and a check valve shall be installed on the discharge pipeline; alternatively, with a leak monitoring device and a quick shut-off valve, the absorbent can be quickly and automatically cut off in the event of leakage. When this design is adopted, the capacity of the drip trays shall be sufficient to accommodate potential leaks.

3.8.5 Reboiler

The reboiler heats the organic amine solution that has absorbed carbon dioxide to a suitable temperature via a heat source, thereby desorbing carbon dioxide from the organic amine solution. The reboiler shall meet the following requirements:

(1) The materials of the main components of the reboiler shall consider the applicable temperature, pressure, and medium, and shall meet the requirements of CCS “Rules for Materials and Welding”.

(2) There shall be certain safety measures to protect the reboiler from damage due to overpressure.

(3) A liquid level gauge shall be installed on the shell of the reboiler to monitor the equipment liquid level. Pressure and temperature measuring devices are installed in the inlet and outlet pipelines of the reboiler to monitor equipment operating parameters.

(4) The equipment interface shall have sufficient stiffness and strength to withstand significant external pipe forces.

(5) The reboiler shall be provided with all-fixed insulation layers and necessary evacuation and drainage interfaces.

3.8.6 Organic amine solution treatment system

(1) Since there is the possibility of overpressure in the organic amine solution treatment device and its components, a suitable pressure relief device shall be installed.

(2) The installation and arrangement of filters shall ensure that the operation of OCCS is not interrupted during cleaning or replacement.

(3) The turbidity/suspended particulate matter of the treated organic amine solution shall meet the system use requirements.

3.8.7 Redundance

Redundant configuration shall be provided for pumps that are important for continuous operation of the OCCS system.

Chapter 4 Control, Monitoring and Safety Protection

4.1 General Requirements

4.1.1 The control system of the OCCS controls the induced draft fan, the circulation volume of organic amine solution, the OCCS operation status, the bypass status, the desorption status of the absorption liquid, the working status of the core equipment such as the compressor, the liquefaction unit, and the liquid carbon dioxide storage tank, etc. It is capable of adjusting the parameters of the OCCS according to the status of the combustion unit such as the engine and the boiler, and exchanging the data externally.

4.1.2 The control, monitoring, and safety systems of the OCCS shall meet the requirements of this chapter, in addition to meeting the requirements of the relevant requirements of Chapter 3.

4.1.3 OCCS shall have fault self-diagnosis and safety protection function, when a fault occurs, the system shall immediately carry out fault diagnosis and start the corresponding safety protection function.

4.1.4 The OCCS data logging and processing equipment shall be capable of outputting system status, data and alarms to the ship's monitoring system via an external interface.

4.1.5 Sensors and monitoring equipment related to emissions shall be reliable and accurate and shall be calibrated periodically, with acceptable calibration procedures from the designer or equipment.

4.2 Control

4.2.1 The induced draft fan device shall be able to realize automatic control operation and run automatically when the pressure difference between the front and rear of the absorption device exceeds the set value, or set up a reasonable opening frequency and continuous working time to ensure that the pressure difference is reasonable. In addition, manual control function shall also be set up in order to carry out debugging test work.

4.2.2 The OCCS shall be capable of automatically controlled operation, and the exhaust gas temperatures corresponding to operation and stopping shall be consistent

with the technical documentation.The OCCS shall also be equipped with a manual control function for manual operation.

4.2.3 The compression and liquefaction device shall be able to realize automatic control operation, and the carbon dioxide gas pressure corresponding to operation and stop shall be consistent with the technical documents, and manual commissioning work can be carried out.

4.3 Monitoring

4.3.1 The monitoring function of the OCCS electronic control system shall be capable of alerting the system to major functional faults in the sensors, electronic control units and actuators.

4.3.2 Sensors in the control system that may affect the proper operation of the OCCS due to a malfunction, especially sensors affecting the absorption and desorption of organic amines or the compression and liquefaction of carbon dioxide, as well as storage, shall be capable of when malfunctioning or failing:

(1) Sends an alarm signal;

(2) Ease of maintenance, including, but not limited to, the ability to restore normal control functions after replacing damaged parts or putting in spare equipment;

4.3.3 The control unit of OCCS shall be able to effectively monitor the working status of key components such as carbon dioxide absorption unit, carbon dioxide desorption unit, carbon dioxide compression unit, carbon dioxide liquefaction storage unit, organic amine solution supply unit and carbon dioxide storage tank, etc. The specific items shall be referred to the table of monitoring items in Article 4.5 of this chapter.

4.4 Security System

4.4.1 If electromechanical equipment stops due to the action of a safety system, an alarm shall be given and the fault indicated, and the equipment shall not be automatically put back into operation except by manual reset.

4.4.2 The OCCS shall be equipped with a safety device capable of automatically stopping the organic amine solution pumps in the system in the event of any of the following malfunctions:

(1) Abnormally high liquid level in the exhaust gas cooling unit (if any) or carbon dioxide absorption unit;

(2) Abnormally high pressure at the inlet of the exhaust gas cooling unit (if any) or abnormally high differential pressure between the inlet of the exhaust gas cooling unit and the outlet of the carbon dioxide absorber.

4.4.3 The exhaust gas bypass mechanism (if any) shall be equipped with an interlocking mechanism that prevents the OCCS channel and the bypass line from being closed at the same time due to misoperation. The bypass shall be operated in such a way that the bypass valve is fully open before the OCCS channel is closed. Mechanical actuated valves are also acceptable and are not subject to the bypass procedure described above. If a bypass line device is installed, the device shall be capable of automatically opening the bypass in the event of any of the following failures:

(1) Abnormally high liquid level in the exhaust gas cooling unit (if any) or carbon dioxide absorption unit;

(2) Abnormally increased pressure at the inlet of the exhaust gas cooling unit (if any) or abnormally high differential pressure between the inlet of the exhaust gas cooling unit and the inlet and outlet of the carbon dioxide absorber unit;

(3) The temperature at the outlet of the carbon dioxide absorption unit was abnormally high.

4.5 OCCS Monitoring Project Sheet

4.5.1 The OCCS monitoring program shall meet the requirements of Table 4.5.1.

4.5.2 OCCS with different control strategies shall have different monitoring programs, and additional monitoring programs shall be added based on the results of the system's FMEA report analysis.

OCCS Monitoring Program **Table 4.5.1**

Item	Control station (room)		Safety system action category		Note
	Demonstrate	Limit Alarm	Automation cessation	* Bypass	

1 OCCS Operating Status					
OCCS work	Running indication	-	–	–	
Bypass	State of affairs	Failed to open	–	–	
2 Carbon Dioxide Absorption Unit					
* Exhaust gas cooling unit level	-	High	X	**X**	
* Exhaust gas cooling unit inlet pressure strength	Pressure	High	–	–	
		Too high	X	X	
Exhaust gas cooling unit inlet and carbon dioxide absorption unit outlet. Pressure difference	Pressure difference	High	X	X	
Flue gas temperature	Temp	High	X	–	
Carbon dioxide absorption unit liquid level	-	High	X	–	
Carbon dioxide absorption unit pressure	-	High	X	–	
Carbon dioxide absorption unit outlet temperature	Temp	High	- -	**X**	
3 Carbon Dioxide Desorption Unit					
Carbon dioxide desorption unit temperature	Temp	Low	**X**	–	
Carbon dioxide desorption unit pressure	-	High	X	–	
Carbon dioxide desorption unit Liquid level	–	High	X	–	
Desorption pumps	-	Malfunctions	–	–	Start the backup pump
4 Carbon Dioxide Compression Unit					
Run/shutdown	Run	Fault/Em	X	-	

	indication	ergency			
Cooling pump failure	-	Malfunctions	–	–	Start-up pumps
Temperature in liquid and vapor piping systems in carbon dioxide refrigeration systems	Temp	High/Low	–	–	
Pressure in liquid and vapor piping systems in carbon dioxide refrigeration systems	Stresses	High	–	–	
5 Carbon Dioxide Liquefaction Storage Unit					
Run/shutdown	Running indication	Fault/Emergency	X	-	
Discharge Pump Failure	-	Malfunctions	–	–	Start the backup pump
Sensor failure	-	Malfunctions	X	-	
Carbon dioxide tank level	Liquid level	High	–	–	
Carbon dioxide tank pressure	Stresses	High	–	–	
Carbon dioxide tank temperature	Temp	High/ Low	–	–	
Pressure in the vapor space of a carbon dioxide storage tank	Stresses	High/ Low	–	–	
Carbon dioxide content of the storage space of carbon dioxide storage	Carbon dioxide content	High	–	–	

tanks					
6 Electronic Control Unit					
Control unit power supply failure	Input voltage	Malfunctions	-	-	Voltage can be replaced by an indicator light
Control system communication failure	-	Malfunctions	X	X	
Failure of major sensors, electronic control units, actuators (control-related)	-	Malfunctions	X	X	
7 Auxiliary Unit					
Liquid level in circulating tank of organic amine solution	Liquid level	Absorbent side low level	X	-	
Organic amine solution circulation tank temperature	Temp	High	X		
Supply pumps	-	Malfunctions	--	--	Start the backup pump
Organic amine spray master line flow	flux	--	--	--	
Reboiler level	Liquid level	--	--	--	

Note: Symbols and their meanings in the table: (1) -: setting not required; (2) X: applicable; (3) *: as sometimes.

Chapter 5 OCCS Test Technical Requirements

5.1 General Requirements

5.1.1 For OCCS with the same design but different specifications, if they are designed according to the scaled-down principle, type approval may be granted for the whole series after selecting typical samples for type testing. 3For type approval of a series of products, in principle, a scaled-down prototype test and an on-board confirmation test of the full-size product shall be carried out, and the minimum specification of the scaled-up prototype shall be the applicable combustion unit with a power of not less than 500kW or an exhaust gas volume of not less than 5000m^3/h, and the scaling range of the scaled-up prototype shall not be more than 50 times. The principles of scaling are described in clause 5.2 of this chapter.

5.1.2 OCCS shall confirm that the series of drawings within its scope of approval (as required in Chapter 2 of this Guide) have been approved and by CCS prior to the conduct of the type test.

5.2 Scaling Principle

5.2.1 The OCCS, designed using the principle of proportional scaling and applicable to different combustion unit exhaust gas flows, shall meet the following requirements:

(1) The test shall be carried out using the exhaust gas from the combustion unit, the composition of which shall meet the applicable range.

(2) The gas velocity of the absorption unit and the exhaust gas cooling unit shall be the same or meet the applicable range.

(3) The gas-liquid ratio of the absorption unit and the exhaust gas cooling unit shall be consistent or meet the applicable range.

(4) The composition, type and concentration of absorbents used shall be consistent.

(5) The proportion of absorbent used for absorption and desorption shall be consistent.

(6) Desorption unit gas velocities shall be consistent or meet the applicable range.

(7) Desorption vapor temperature and pressure shall be consistent or meet the applicable range.

(8) Control strategy development rules shall be consistent.

5.3 Selection of Typical Prototypes

5.3.1 For initial approval, each series of OCCS shall select a set of equipment for type test. The selected prototype is representative in technical parameters, structure and manufacturing process, reflecting the processing capability and manufacturing level of the factory.

5.3.2 The engine + OCCS selection for the validation test shall meet the following requirements:

(1) OCCS can be a prototype for design development or a specific shipment.

(2) The test engine may be used without the proposed engine, provided that the engine is rated for the maximum gas flow rate applicable to the OCCS.

(3) If it is not possible to select the appropriate engine as a prototype due to the size and conditions of the prototype, and if it can be demonstrated by calculations or modeling that the OCCS maximum gas flow rate is applicable to the engine and that there is a margin for error, a reduction in the requirements of the above article may be considered, and, if necessary, may be verified by confirmation tests on board.

5.4 OCCS Type Test Program

5.4.1 OCCS shall perform the type test items listed in Table 5.4 and submit the corresponding test reports.

OCCS Type Test Items Table 5.4

Serial number	Pilot project		Inspection Requirements (Articles of this Guide)	Clarification
1	System integrity check		5.5.1	
2	Absorbent performance test	Physical and chemical performance test	5.5.2 (1)	
		Absorption performance test	5.5.2 (2)	
3	Electronic control system test		5.5.3	

4	OCCS performance test	Phase I: absorption, desorption energy test	5.5.4 (1)	
		Phase II: Compression and liquefaction performance test	5.5.4 (2)	
		Phase III: On-board validation tests	5.5.4 (3)	

5.5 Type Test Requirements

5.5.1 System integrity check. the OCCS and its components meet the technical requirements of the approved drawings and Chapter 3 of this guide.

(1) OCCS Absorption Unit, Desorption Unit Inspection Requirements.

① Internal and external structure, including the shape and size of the device and the form of arrangement of the internal structure;

② Airtightness test: Generally, 1.1 times the design pressure or according to the factory requirements.

(2) Absorbent supply pumps, nozzles and piping, etc.

(3) System integrity. For example, absorption units, desorption units, compression units, liquefaction units, etc.

5.5.2 Absorbent performance test

(1) Absorbent physicochemical performance test.

Key physicochemical parameters such as pH and viscosity of the absorbent were determined.

(2) Absorbent absorption performance test.

The absorption performance test is conducted on a test stand, and the absorption device can be connected to the engine in accordance with the conditions of the test stand to verify the absorption capacity under specific test conditions, such as at a certain inlet exhaust gas temperature, gas-liquid ratio and so on.

5.5.3 Electronic control system test

(1) The type test of the electronic control system shall meet the requirements of this section in addition to the relevant requirements of the Society's Guide to Accredited Testing of Electrical and Electronic Products.

(2) Control function test of the electronic control system. Confirms that the electronic control system responds as expected during OCCS operation and verifies control parameters.

(3) Functional tests such as safety protection and fault monitoring and alarm are determined in accordance with the relevant requirements in Chapter 4 of this guide.

5.5.4 OCCS Performance Test

(1) Absorption and desorption performance test

The OCCS absorption and desorption performance test based on an onshore isosceles test shall verify the CO2 absorption capacity, CO2 desorption purity and desorption vapor consumption at the maximum design conditions of the system. In addition to the maximum design conditions, at least one additional condition shall be verified.

① Carbon dioxide absorption capacity

Select a specific operating point of the engine exhaust gas, adjust the exhaust gas cooling device so that the temperature of the exhaust gas at the inlet of the absorption device is consistent with the performance test of the absorber, control the absorber spraying volume of the absorption device to the gas-liquid ratio of the system is consistent with the performance test of the absorber, and according to the carbon dioxide concentration of the exhaust gas inlet and outlet of the absorption device at the time when the system is stabilized, the carbon dioxide absorption capacity of operating point is determined.

② Desorption of carbon dioxide purity

On the basis of 5.5.4(1)(1) carbon dioxide absorption capacity test, measure the carbon dioxide purity of the gas condensed at the outlet of the desorption device, and verify the purity of carbon dioxide separated by desorption of the OCCS under different operating conditions of the engine.

③ Desorption vapor consumption

On the basis of 5.5.4(1)(2) purity test of desorbed carbon dioxide, determine the consumption of desorbed vapors under different exhaust gas operating conditions.

(2) Compression and liquefaction performance tests;

Adopting the same design and configuration of compressor and refrigeration unit as that of the actual ship, the OCCS carbon dioxide compression and liquefaction storage test is carried out to verify the energy consumption of carbon dioxide gas compression and liquefaction and the safety feasibility of the process route under the designed storage pressure and temperature conditions.

(3) Onboard confirmation test.

① Confirmation test shall include function test and performance test, and the performance parameters shall meet the design value.

② All components, operating values or settings that may affect the operation and performance of the OCCS unit shall be included in the Onboard confirmation test program.

③ The Onboard confirmation test procedure shall be submitted by the OCCS manufacturer to the Society for approval.

④ The Onboard validation test procedure shall include documentary verification and physical inspection by OCCS.

⑤ The surveyor shall verify that each OCCS is installed in accordance with the requirements of the System Technical Manual.

⑥ The OCCS shall have a facility to automatically record operating parameters during system operation, which shall include, at least, the following: carbon dioxide concentration at the inlet of the absorption unit of the OCCS unit, the carbon dioxide concentration of the exhaust gas at the outlet, the absorber recirculation flow rate, the temperature of the gas at the outlet of the desorption unit, the concentration and flow rate of carbon dioxide, the reboiler vapor parameter, and the pressure and temperature of the storage tank. If the OCCS unit consumes chemical substances at the rate specified in the System Technical Manual document, the record of chemical substance consumption in the OCCS logbook may also be included as part of the data record.

⑦ The shipowner shall keep an OCCS record book to record information on OCCS operation, maintenance, and replacement of parts. The format of the record shall be submitted by the OCCS manufacturer to the Society for approval. The record book shall be available when required for inspection and shall be used in conjunction with the engine log and other necessary data to confirm the correct operation of the OCCS. OCCS operation, maintenance and component replacement information may also be recorded in the approved ship's planned maintenance system.

5.5.5 OCCS Technical Manual

(1) Each OCCS shall have a copy of the technical manual provided by the manufacturer, which shall include at least the following:

① System identification (make, model, serial number and other necessary details), including a description of the system.

② OCCS Working Boundary Scope, including at least:

(a) Absorbent type, major components, pH and viscosity information;

(b) OCCS Maximum pressure loss before and after;

(c)Applicable fuel quality and standards, maximum fuel sulfur content;

(d) Organic amine solution life;

(e)Carbon dioxide emission reduction efficiency;

(f) Maximum exhaust gas flow rate applies;

(g) Maximum CO2 Absorb capacity;

(h) Desorption temperature;

(i) Desorption of carbon dioxide purity;

(j) Desorption vapor consumption;

(k) Maximum compression pressure;

(l) Compression unit energy consumption;

(m)Liquefaction temperature;

(n) Storage pressure;

(o) Storage temperature;

(p) Liquefy storage unit energy consumption.

③ Any requirements or qualifications relating to OCCS or related equipment.

④ Corrective action to be taken when OCCS operating conditions exceed approved ranges or limits;

(2) OCCS technical manuals shall be kept on board in case they are required for inspection.

(3) If changes are made to the OCCS that affect the performance of carbon dioxide capture and liquefaction storage, changes to the Technical Manual to reflect those changes shall be approved by CCS. Additions, deletions, or modifications to the contents of the Technical Manual that are independent of the originally approved Technical Manual shall be maintained with the Technical Manual and considered part of the Technical Manual.

5.6 Unit/batch Inspection

5.6.1 After obtaining CCSapproved, OCCS produced by the factory under the accredited conditions can apply for CCS for Unit/batch inspection.

5.6.2 After the approval of the Unit/batch items shall meet the requirements of Table 5.6.2, and submit the corresponding test report after the completion of the test:

OCCSUnit/batch inspection **Item Table 5.6.2**

Serial number	Pilot project	Inspection Requirements
1	System integrity check	This Guide 5.5.1.
2	Control software version number	Verification of information such as version numbers of control software
3	OCCS Technical Manual Approval	(1) Confirm that the product is suitable for the proposed matching oil burning device. (2) Comply with the requirements of this guide.

4	Functional check of the electronic control system	Alarm point, stop point

5.6.3 Upon completion of the Unit/batchinspection, CCS issues a marine product certificate and approves the OCCS Technical Manual prior to issuance of the certificate.

5.7 Certificates

5.7.1 OCCS shall issue the appropriate certificates after passing the accredited inspection as required by these guidelines and shall approve the OCCS Technical Manual prior to issuance of the certificate.

5.7.2 OCCS Certificates of approved and Product Certificates shall include the elements listed in the OCCS Working Boundary Parameters Table in Appendix 1 of this Guide.

5.7.3 OCCS certificates of approval and product certificates shall have a parts list (list of components) to show the composition of the system. The parts list for the Certificate of Approval shall include: part name, model, specification or material and other information; the parts list for the Product Certificate shall include: part name, specification or material, part number and other information.

5.7.4 OCCS shall apply for our inspection and issuance of certificates after installation of the wholesystem; if the system is supplied in bulk and application is made for single piece/single batch inspection without forming a complete system at the place of inspection, the need for additional inspections and tests as well as the number of the document on which they are based shall be listed on the product certificate.

Appendix 1 Table of OCCS Working Boundary Parameters

1. Absorbent	
Type/Model/Specification	
Base	
Applicable working temperature range	
pH	
Stickiness	

Absorbent life	
2. System parameters	
Maximum pressure loss before and after unit (100% operating condition) (kPa)	
Applicable gas composition, e.g. NOx, SOx, CO_2 concentration	
System absorption capacity (%)	
Energy consumption per unit of capture ($GJ/t\text{-}CO_2$)	
Maximum system electrical power (kW)	
3. Absorption unit	
Maximum exhaust gas flow	
Maximum absorption capacity	
4. Desorption unit	
Desorption temperature	
Desorbed carbon dioxide purity (%)	
Desorption vapor consumption (t/h)	
5. Compression unit	
Compressor Displacement	
Compressor pressure	
6. Liquefied storage unit	
Liquefaction temperature	
Storage pressure	
Storage temperature	

NOTE: The following remarks shall be added to the remarks column of the product certificate: The volume of tanks required for the vessel shall be calculated based on the actual capture volume and storage time.

Appendix 2 OCCS Licensing Requirements

Appendix List of Licensing Requirements for Proprietary Products for OCCS

No.	Product Name	Document		Approval model				Plan approval	Remarks note
		C/E	W	DA	TA-B	TA-A	WA	PA	
1	CO_2 Absorbers	X	-	-	-	-	-	X	
2	CO_2 Desorption Unit	X	-	-	-	-	-	X	
3	Liquid CO_2 Pump	X	-	-	X	-	-	X	
4	Organic Amine Solution Pumps	X	-	-	X	-	-	X	
5	Reboiler	X	-	-	-	-	-	X	
6	Refrigeration system	X	-	-	-	-	-	X	
7	CO_2 Storage Tank	X	-	-	-	-	-	X	
8	Compression Unit	X	-	-	-	-	-	X	
9	Organic amine treatment unit	X	-	-	-	-	-	X	
10	Electronic Control System	X	-	-	-	-	-	X	The first manufactured part shall be type test
11	Organic Amine Solution tanks	X	-	-	-	-	-	X	

NOTE*: OCCS General Purpose Equipment shall meet the symbol descriptions for the licensed list requirements in Chapter 3 of Title I of the Steel Code:

1) C-Marine Product Certificate; E-Equivalent Documentation; W-Manufacturer's Certificate; X-Applicable; O-Optional;

2) DA-Design Approval; TA-B-Type approval B; TA-A-Type approval A; WA-Work Approval; PA-Plan Approval.