

Requirements for

Onboard Carbon Capture and Storage



December 2022



REQUIREMENTS FOR

ONBOARD CARBON CAPTURE AND STORAGE
DECEMBER 2022

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Foreword (1 December 2022)

The increased commitment from the International Maritime Organization (IMO) to reduce Green House Gas (GHG) emissions from shipping is expected to drive the adoption of sustainable marine fuels and non-petroleum based fuels. However, to limit global temperature increases in line with the Paris Agreement, a range of measures are anticipated to be applied, including adoption of the aforementioned fuels, improvement of energy efficiency, limits on emissions of high Global Warming Potential (GWP) gases, reduction of CO₂ emissions per transport work and reduction of total GHG emissions from shipping.

To support those objectives, the need to remove CO₂ emissions at the source during production of marine fuels, as well as during the transport or burning of those fuels, is considered a partial solution. Carbon capture for re-use or sequestration has been demonstrated on land-based applications and the transfer of those technologies onboard can be a way to remove CO₂ emissions from the exhaust of hydrocarbon fuel burning equipment, and thus a means to reduce vessel-specific CO₂ emissions and improve the Carbon Intensity Indicator (CII). Accordingly, this document establishes the ABS requirements for the use of Onboard Carbon Capture and Storage (OCCS), focusing on wet scrubbing post-combustion technologies.

Since the range of OCCS technologies may be broad and may be combined with other Exhaust Emission Abatement (EEA) equipment, the applicable requirements will vary on a case-by-case basis. However, the intention is not to hinder application of any novel technologies or systems not prescriptively detailed herein; systems designed for partial or full CO₂ capture will be considered. Pre-combustion or fuel treatment technologies that remove carbon prior to combustion or utilization in energy converters such as internal combustion engines, boilers or fuel cells may also be considered. Systems that remove, process and store carbon in compounds other than CO₂ or use methods other than solvent based scrubbing systems, such as membranes or cryogenic distillation, will also be considered.

The ABS criteria to be applied to EEA equipment, including SO_x scrubbers, Selective Catalytic Reduction (SCR) units, Exhaust Gas Recirculation (EGR) systems and Exhaust Emissions Monitoring Systems (EEMS) are detailed in 6/3 of the *ABS Marine Vessel Rules*. These requirements for OCCS cover only the Classification approval aspects; additional statutory requirements and approvals may be required based on the vessels Flag Administration.

This document extends the range of requirements for EEA equipment to include equipment installed to remove, process and store CO₂ from exhaust emissions. This document provides Classification criteria for the arrangements, construction, installation and survey of machinery, equipment, and systems for marine and offshore assets with installed post-combustion Onboard Carbon Capture and Storage equipment to minimize the risks to the vessel, crew and environment.

The applicable edition of the *Marine Vessel Rules* is to be used in conjunction with this document.

The December 2022 edition includes requirements for the new optional notation **EGC-OCCS Ready**. The purpose of this notation is to indicate the extent to which a vessel has been prepared or ready for compliance with this document and the *Marine Vessel Rules*.

Users of this document should be aware that, due to changing regulations and depending on the specific type of OCCS systems, compliance with this document may not necessarily reflect all requirements at the time of construction or future conversion. It is to be noted that compliance with the applicable edition of this document and the *Marine Vessel Rules* in force at the time the **EGC-OCCS Ready** service is offered does not guarantee compliance with the later editions of this document or the *Marine Vessel Rules* that may be applicable at the time of installation at a later date.

These requirements become effective on the first day of the month of publication.

Users are advised to check periodically on the ABS website www.eagle.org to verify that this version of this document is the most current.

We welcome your feedback. Comments or suggestions can be sent electronically by email to rsd@eagle.org.



REQUIREMENTS FOR

ONBOARD CARBON CAPTURE AND STORAGE

CONTENTS

SECTION 1	Introduction.....	8
1	General.....	8
2	Scope.....	8
3	Objective.....	9
4	Classification Notations.....	9
4.1	EGC-OCCS.....	9
4.2	EGC-OCCS Ready Notations.....	9
4.3	EEMS.....	9
5	Certification.....	10
SECTION 2	General.....	11
1	Application.....	11
2	Definitions and Abbreviations.....	11
2.1	Absorber.....	11
2.2	Amine.....	11
2.3	Ammonia Water.....	11
2.4	CO ₂ Machinery Space.....	11
2.5	CCS.....	11
2.6	CII.....	11
2.7	Closed Loop.....	12
2.8	CO.....	12
2.9	CO ₂	12
2.10	Desorber.....	12
2.11	EEA.....	12
2.12	EGC.....	12
2.13	EGR.....	12
2.14	EEMS.....	12
2.15	Fuel Oil.....	12
2.16	Fuel Oil Combustion Unit (FOCU).....	12
2.17	GHG.....	12
2.18	GWP.....	12

2.19	HC.....	12
2.20	IMO.....	12
2.21	ISO.....	13
2.22	MARPOL.....	13
2.23	MEGC.....	13
2.24	NaOH Water.....	13
2.25	NOx.....	13
2.26	O2.....	13
2.27	OCCS.....	13
2.28	Open Loop.....	13
2.29	PM.....	13
2.30	PPE.....	13
2.31	Pre-Scrubbing/Quenching.....	13
2.32	Recognized Standard.....	13
2.33	Rules.....	14
2.34	SDS.....	14
2.35	Sublimation.....	14
2.36	SCR.....	14
2.37	Scrubber.....	14
2.38	SOx.....	14
2.39	Triple Point.....	14
3	Objective.....	14
4	Alternatives.....	16
5	Operating and Maintenance Instruction Manuals.....	16
SECTION 3	Ship Arrangements.....	17
1	Plans and Data to be Submitted.....	17
2	Risk Assessment.....	17
3	System Configuration and Vessel Integration.....	18
3.1	EGC Compatibility and Exhaust Bypass.....	18
3.2	Redundancy.....	20
3.3	Essential Services.....	20
3.4	Inclinations.....	20
3.5	Vibration.....	20
3.6	Vessel Stability, Loading and Capacity.....	20
4	OCCS System Location.....	21
4.1	EGC Pre-Scrubbing/Quenching and Absorber Units.....	21
4.2	Desorber or Stripping Units.....	21
4.3	Solvents and Consumables.....	21
4.4	EGC Residues.....	21
4.5	CO2 Processing.....	21
4.6	Liquefied CO2 Storage Tanks.....	22
5	Personal Safety and PPE.....	22

	6	Inspection and Maintenance.....	23
SECTION	4	Pre-Scrubbing/Quenching, Absorber and Desorber Systems.....	24
	1	General.....	24
	2	Plans and Data to be Submitted.....	25
	3	Pre-Scrubbing/Quenching, Absorber and Desorber System Equipment.....	25
	3.1	Pumps/Fans.....	25
	3.2	Exhaust Heat Exchangers.....	26
	3.3	Process Pressure Vessels and Heat Exchangers.....	26
	3.4	Electrical System.....	26
	4	Pre-Scrubbing/Quenching, Absorber and Desorber System Piping.....	27
	5	Monitoring, Alarm and Control Systems.....	30
SECTION	5	CO₂ Compression, Refrigeration and Liquefaction Systems.....	31
	1	General.....	31
	2	Plans and Data to be Submitted.....	31
	3	System Design and Capacity.....	32
	4	CO ₂ Machinery Space.....	32
	5	System Equipment.....	33
	5.1	Reliquefaction and Refrigeration Systems.....	33
	5.2	Materials.....	34
	5.3	Compressors.....	34
	5.4	Separators, Pressure Vessels, and Heat Exchangers.....	34
	5.5	Pumps.....	34
	6	System Piping.....	34
	7	Monitoring, Alarm and Control Systems.....	34
SECTION	6	Liquefied CO₂ Storage.....	36
	1	General.....	36
	2	Plans and Data to be Submitted.....	36
	3	Liquefied CO ₂ Storage Tanks.....	37
	3.1	Design.....	37
	3.2	Materials.....	38
	3.3	Pressure Relief and Venting System.....	38
	3.4	Instrumentation and Monitoring.....	38
	4	Filling Limit and Pressure/Temperature Control.....	39
	5	Emergency Shutdown System.....	39
	6	Unloading Arrangements.....	40
	7	Portable Tanks.....	40
	8	Monitoring, Alarm and Control Systems.....	41

SECTION	7	Monitoring, Alarm and Control Systems.....	42
	1	General.....	42
	2	Plans and Data to be Submitted.....	42
	3	Control and Monitoring System.....	42
	4	Safety Shutdown System.....	43
	5	Gas Monitoring and Detection System.....	43
	6	Exhaust Emission Monitoring Systems.....	44
	TABLE 1	Monitoring and Safety System Functions for Pre-Scrubbing/Quenching, Absorber and Desorber Systems....	44
	TABLE 2	Monitoring and Safety System Functions for Compression, Refrigeration and Liquefaction Systems.....	45
	TABLE 3	Monitoring and Safety System Functions for Liquefied CO ₂ Storage Tanks.....	46
SECTION	8	EGC-OCCS Ready Notation.....	48
	1	General.....	48
	2	Scope and Application.....	48
	3	Ready 1C- Concept Design Review.....	49
	3.1	Plans and Data to be Submitted.....	49
	4	Ready 2D- Detail Design Review.....	49
	4.1	Plans and Data to be Submitted.....	50
	5	Ready 3- Installation Ready Review.....	52
	6	Survey During Construction.....	52
	TABLE 1	EGC-OCCS Ready Notation Subgroups and Descriptive Letters.....	50
SECTION	9	Surveys and Maintenance of Class.....	53
	1	General.....	53
	1.1	Definitions.....	53
	1.2	Modifications.....	53
	2	Survey During Construction.....	53
	2.1	General.....	53
	2.2	Surveys at Manufacturer's Facility.....	53
	2.3	Surveys During Installation.....	54
	2.4	Surveys During Trials.....	54
	3	Survey After Construction.....	55
	3.1	Annual Survey.....	55
	3.2	Intermediate Survey.....	55
	3.3	Special Periodical Survey.....	55
	TABLE 1	Certification of Onboard Carbon Capture Systems at the Manufacturer's Facility.....	56

SECTION 1 Introduction

1 General

The provisions of Part 1, Chapter 1, “Scope and Conditions of Classification” of the *ABS Rules for Conditions of Classification (Part 1)* are applicable to the classification of Onboard Carbon Capture and Storage (OCCS) equipment.

2 Scope

This document extends the range of ABS requirements for Exhaust Emission Abatement (EEA) equipment to include equipment installed to remove, process and store CO₂ from exhaust emissions. Accordingly, this document has been developed to provide guidance for the design, construction, installation, and survey of machinery, equipment and systems for vessels and offshore units with Onboard Carbon Capture and Storage (OCCS) equipment, focusing on wet scrubbing post-combustion technologies. ABS approval is not an endorsement of the effectiveness of the system to capture carbon.

This document is to be applied to both new construction and existing vessels and offshore units, regardless of size, including those of less than 500 tons gross tonnage.

Since the range of OCCS technologies may be broad, and may be combined with other EEA equipment, the applicable requirements will vary on a case-by-case basis. However, the intention is not to hinder application of any novel technologies or systems not prescriptively detailed herein. Systems designed for partial or full CO₂ capture will also be considered. Pre-combustion or fuel treatment technologies that remove carbon prior to combustion or use in energy converters such as internal combustion engines, boilers or fuel cells may also be considered. Systems that remove, process and store carbon in compounds other than CO₂ or use methods other than solvent-based scrubbing systems, such as membranes or cryogenic distillation, will also be considered. Solutions that have been verified to meet the objective and intent of this document will be accepted for installation on ABS vessels and offshore units. See also Subsection 2/4 regarding the approval of alternatives.

For more information on the approval of novel concepts and new technology qualification, see the *ABS Guidance Notes on Review and Approval of Novel Concepts* and the *ABS Guidance Notes on Qualifying New Technologies*.

The ABS criteria to be applied EEA equipment, including SO_x scrubbers, Selective Catalytic Reduction (SCR) units, Exhaust Gas Recirculation (EGR) systems and Exhaust Emissions Monitoring Systems (EEMS) are detailed in Part 6, Chapter 3 of the *Marine Vessel Rules*.

Those Classification requirements are separate and additional to any statutory requirements that may be applicable under IMO’s MARPOL Annex VI, NO_x Technical Code or associated guidelines.

Carbon capture systems are recognized as one of the carbon reduction technologies. Refer to the ABS *Guide for Sustainability* for **SUSTAIN** Notations.

3 Objective (1 December 2022)

The objective of this document is to provide Classification criteria for the arrangement, construction, installation and survey of machinery, equipment and systems for marine and offshore assets with installed post-combustion OCCS equipment to minimize risks to the vessel, crew and the environment.

This document also applies to vessels that have design features considered for future installation of an OCCS equipment.

4 Classification Notations

4.1 EGC-OCCS

Where an OCCS system is fitted onboard, the **EGC-OCCS** notation is mandatory and will be assigned where the OCCS system is designed, constructed, and tested in accordance with the requirements of this document.

Where parts of an OCCS system that is primarily designed for the removal of CO₂ also meet the requirements of Part 6, Chapter 3 of the *Marine Vessel Rules*, for example the pre-scrubbing/quenching unit, those parts may be assigned the additional optional, **EGC-SO_x** notation, subject to the pre-scrubbing/quenching unit being verified to be designed, constructed, and tested in accordance with the SO_x scrubber requirements of Section 6-3-2 of the *Marine Vessel Rules*.

4.2 EGC-OCCS Ready Notations (1 December 2022)

Where a vessel has design features suitable to permit conversion at a future date for the installation of an OCCS Equipment, the following optional notations may be assigned based on the level of readiness:

- **EGC-OCCS Ready 1C** indicates a high-level evaluation of the compliance of the basic suitability of a particular vessel design to fit an OCCS system.
- **EGC-OCCS Ready 2D** indicates a detailed evaluation of the compliance of the suitability of a particular vessel design to fit an OCCS System.
- **EGC-OCCS Ready 3** extends the Class approval of the drawings to the installation of parts of the system or complete system onboard the vessel including Survey in accordance with applicable requirements of this document and related *Marine Vessel Rules*.

Full details of the optional **EGC-OCCS Ready** notations including descriptive letters and the requirements for assigning the notations are provided in Section 8.

Note:

In the future, once the vessel has undergone installation of the complete OCCS System onboard that is shown to be in compliance with the *Marine Vessel Rules* and this document, in accordance with approved plans and operationally tested and commissioned to the satisfaction of the Surveyor, the above **EGC-OCCS Ready** notations will be dropped and the **EGC-OCCS** notation will be assigned.

4.3 EEMS

Where a vessel is fitted with an exhaust emission monitoring system (EEMS) for monitoring NO_x, SO_x, CO, HC, CO₂ or other gaseous and particulate matter (PM) emissions, the **EEMS** notation is optional and will be assigned where the emission monitoring system is designed, constructed, and tested in accordance with the requirements of this document and Section 6-3-5 of the *Marine Vessel Rules*.

5 Certification

ABS design review, survey, testing, and the issuance of reports or certificates constitute the certification of machinery, equipment and systems; see also 4-1-1/3 of the *Marine Vessel Rules*.

1 Application

The requirements of this document are to be applied to an OCCS system designed for installation on marine vessels and offshore units.

2 Definitions and Abbreviations

2.1 Absorber

A component of the OCCS system designed to absorb CO₂ into an absorber media such as an amine solvent, ammonia water, NaOH water.

2.2 Amine

An organic compound derived from ammonia by replacement of one or more hydrogen atoms by organic groups.

Commentary:

Amines are used to remove CO₂ in various industries ranging from natural gas production to the food and beverage industry. Commonly referred to as amine scrubbing, or gas sweetening, gases are processed by using aqueous solutions of various alkylamines, typically referred to as simply amines. Monoethanolamine, Diethanolamine, Methyldiethanolamine and Diglycolamine are examples of amines.

End of Commentary

2.3 Ammonia Water

An ammonia solution, aqueous ammonia, or aqua ammonia, solution of ammonia gas in water, a common commercial form of ammonia, ammonium hydroxide.

2.4 CO₂ Machinery Space

Spaces where the CO₂ compressors, cooling, drying and liquefaction plant and pumps are located.

2.5 CCS

Carbon Capture and Storage.

2.6 CII

Carbon Intensity Indicator.

2.7 Closed Loop

Refers to OCCS systems that use washwater and/or solvent systems in the pre-scrubbing/quenching, absorber and desorber units in a continuous recirculation loop with no external discharge.

2.8 CO

Carbon Monoxide.

2.9 CO₂

Carbon Dioxide.

2.10 Desorber

Also known as a stripping unit; a component of the OCCS system designed to remove, or desorb, the CO₂ from the absorber media.

2.11 EEA

Exhaust Emission Abatement.

2.12 EGC

Exhaust Gas Cleaning.

Commentary:

The term EGC may be used to describe the parts of the OCCS system that directly treat the exhaust gases, for example, the pre-scrubbing/quenching units.

End of Commentary**2.13 EGR**

Exhaust Gas Recirculation.

2.14 EEMS

Exhaust Emissions Monitoring System.

2.15 Fuel Oil

Any fuel delivered to and intended for combustion purposes for propulsion or operation on board a vessel, including gas, distillate, residual, alcohol, or bio derived fuels from petroleum refining or derived by methods other than petroleum refining.

2.16 Fuel Oil Combustion Unit (FOCU)

Any engine, boiler, gas turbine, or other fuel oil fired equipment, excluding shipboard incinerators.

2.17 GHG

Green House Gas.

2.18 GWP

Global Warming Potential.

2.19 HC

Hydrocarbon.

2.20 IMO

International Maritime Organization.

2.21 ISO

International Organization for Standardization.

2.22 MARPOL

The IMO International Convention for the Prevention of Pollution from Ships, 1973, as modified by the protocol of 1978.

2.23 MEGC

Multi Element Gas Containers.

2.24 NaOH Water

Sodium hydroxide in water, which appears as a colorless solution. Sodium hydroxide is colorless.

2.25 NO_x

Nitrogen Oxides. Predominantly containing NO and NO₂ components and typically calculated as the total weighted emission with mass reference for NO₂ and determined using the relevant test cycles and measurement methods of the IMO NO_x Technical Code or ISO 8178.

2.26 O₂

Oxygen.

2.27 OCCS

Onboard Carbon Capture and Storage.

Commentary:

Depending on the OCCS technology applied, several discrete systems may make up the complete OCCS processing system. For example, an absorber/amine solvent OCCS installation may include an exhaust pre-scrubbing/quenching unit (like a wet Sox scrubber), an absorber unit (transfer CO₂ to absorber media), a desorber or stripping unit (which removes CO₂ from absorber media), followed by further CO₂ processing and cleaning steps, including compression and cooling to liquefy the CO₂, which is then transferred to the dedicated CO₂ storage and temperature/pressure management system.

End of Commentary**2.28 Open Loop**

Refers to OCCS systems that use washwater, typically seawater, in the pre-scrubbing/quenching units where the washwater is passed through the EGC unit only once before being discharged overboard.

2.29 PM

Particulate Matter.

2.30 PPE

Personnel Protective Equipment.

2.31 Pre-Scrubbing/Quenching

A unit that cleans and cools the exhaust gas prior to the CO₂ removal process, typically using seawater in an open loop arrangement, however the exhaust gas cleaning and cooling functions may be performed in separate units or utilize alternative methods.

2.32 Recognized Standard

An international or national standard acceptable to ABS.

2.33 Rules

The applicable edition of the *ABS Rules for Building and Classing Marine Vessels (Marine Vessel Rules)*.

2.34 SDS

Safety Data Sheet (SDS). Previously referred to as Material Safety Data Sheet (MSDS) or Product Safety Data Sheet (PSDS).

2.35 Sublimation

The transition of a substance directly from the solid state to a gas state with no passage through the liquid state. This occurs at specific temperatures and pressures below the triple point.

2.36 SCR

Selective Catalytic Reduction. An exhaust aftertreatment system whereby the exhaust gases are mixed with a reductant, such as ammonia introduced in a urea/water solution, and passed over a catalyst, such as vanadium, located in the downstream exhaust system for the purposes of NO_x reduction of the exhaust gases.

A *High-Pressure SCR* is an SCR system integrated onto an engine before the exhaust gas passes through the turbo charger.

A *Low-Pressure SCR* is an SCR system integrated onto an engine after the exhaust gas passes through the turbo charger.

2.37 Scrubber

A generic term used to describe an exhaust gas treatment unit that is designed to remove, or scrub, gaseous compounds for further treatment; SO_x scrubbers are an example, and the wet scrubbing process is utilized in pre-scrubbing/quenching, absorber and desorber OCCS units.

2.38 SO_x

Sulfur Oxide emissions. All sulfur emissions from fuel oil combustion machinery are caused by the combustion reactions with the sulfur introduced by the fuel, which predominately include SO₂ and SO₃ emissions and are typically quantified as SO₂ emissions.

2.39 Triple Point

The transitions point on a phase diagram where all three phases of a gas can exist in equilibrium. For CO₂ the triple point is 0.518 MPa absolute at -56.6°C and at atmospheric pressure solid CO₂, known as dry ice, sublimates from solid to gas at -78.5°C.

3 Objective

The goals and principles of this document are to provide Classification criteria for the arrangements, construction, installation and survey of machinery, equipment, and systems for marine and offshore assets with installed OCCS equipment to minimize risks to the vessel, crew, and environment.

Detailed requirements are provided in each of the Sections of this document to achieve this objective, as applicable to the specific OCCS design, in accordance with the following key principles and requirements:

- Installation and operation of an OCCS system is to be compatible with the fuel oil combustion unit(s) and is not to cause any adverse effects on performance, such as excessive back pressures/temperatures and engine makers pre-approval is required.
- OCCS systems are to be designed to enable continued operation of the fuel oil combustion unit(s) during times when the EGC parts of the OCCS system are not in operation, either through operational selection, equipment failure, or system deterioration through partial blocking/clogging to enable continued operation of the fuel oil combustion unit(s).

- Materials of construction and workmanship are to be in accordance with the requirements of the ABS *Rules for Materials and Welding (Part 2)* and ABS *Rules for Building and Classing Marine Vessels Part 5C-8-6*, as applicable, or to an alternate standard specifically approved in accordance with the design of the OCCS system. When selecting materials, due consideration is to be given to the corrosive nature of the exhaust gases, process media and gas stream.
- OCCS systems and their associated equipment and systems are to be designed to minimize the risks associated with the storage, handling, consumption, and disposal of hazardous or non-hazardous chemicals, solvents, or consumables essential for operation of the OCCS system. Appropriate Personnel Protective Equipment (PPE), together with emergency treatment facilities, appropriate to the hazards concerned, are to be provided.
- Means are to be provided to suitably mitigate the risk to the fuel oil combustion unit(s) or vessel from internal flooding associated with water scrubbing systems.
- Redundancy of equipment is to be provided for those rotating and reciprocating components that form part of the OCCS auxiliary systems, such as pumps, fans, and compressors, and due diligence is to be exercised and demonstrated in the assessment of critical components, equipment, and systems. Alternatively, the carriage of spare parts onboard or alternative means of compliance or operation will be considered to meet this objective.
- OCCS systems are to be designed and installed to avoid the presence of dangerous or detrimental vibration that reduce the safety and reliability of the installed equipment or pose a hazard to the vessel or crew.
- OCCS systems are to be designed to be fully functional for the expected ship motions, including all degrees of list and trims per 4-1-1/ Table 7 of the *Marine Vessel Rules*.
- Means are to be provided to prevent the passage or leakage of exhaust gases to other equipment or spaces that may then pose a safety risk to that equipment or a health risk to the vessel's crew or passengers.
- Means are to be provided to mitigate or limit any potentially hazardous, toxic, or environmentally damaging pollutants that may be introduced to the exhaust gases because of the OCCS system operation.
- Means are to be provided to process and store the captured CO₂, and for the equipment, piping, and containment of the CO₂ to be appropriately arranged to mitigate the risk to the crew, vessel, or environment from chemical, gaseous, liquid or solid leaks or venting that may occur during operation of the OCCS systems.
- Hot surfaces of OCCS systems or their associated equipment or systems likely to come into contact with the crew during operation are to be suitably guarded or insulated.
- Cold surfaces of OCCS systems, or their associated equipment or systems, likely to come into contact with the crew during operation are to be suitably guarded or insulated.
- Appropriate storage and operational arrangements and procedures are to be in place for any specialized or hazardous gases used in OCCS systems or monitoring systems.
- Automation, instrumentation, monitoring, and control systems are to be provided to facilitate automated operation and monitoring of OCCS systems.
- Means are to be provided for the safe storage and disposal of any exhaust residues or process media associated with operation of the OCCS systems.
- Fire protection, detection and extinguishing arrangements are to be provided to protect the vessel and crew from possible fire hazards associated with the operation of OCCS systems and their associated systems.
- OCCS systems are to be arranged for easy inspection and maintenance and where applicable the ability to replace internal components is to be provided.

- Operation and maintenance manuals are to be provided for all OCCS systems and associated equipment and systems to facilitate handling, operation, maintenance, and repair.

4 Alternatives

Equipment, components, and systems for which there are specific requirements in this document, or its associated references, may incorporate alternative arrangements or comply with the requirements of alternative recognized standards in lieu of the requirements in this document. However, this is subject to such alternative arrangements or standards being determined by ABS as being not less effective than the overall safety and strength requirements of this document or associated references. Where applicable, requirements may be imposed by ABS in addition to those contained in the alternative arrangements or standards so that the intent of this document is met. In all cases, the equipment, component or system is subject to design review, survey during construction, tests and trials, as applicable, by ABS for purposes of verification of its compliance with the alternative arrangements or standards. The verification process is to be equivalent to that outlined in this document. See also 4-1-1/1.7 of the *Marine Vessel Rules*.

5 Operating and Maintenance Instruction Manuals

Detailed instruction manuals are to be provided onboard, covering operations between dry-dockings, safety, emergency shutdown, maintenance and training requirements and occupational health hazards relevant to the particular OCCS and associated systems.

The manuals are to include, but are not limited to, the regular testing, calibration and maintenance procedures and schedules for the control and monitoring systems, alarm settings, safety shut-off systems, and the integrity of backup systems together with identification of the relevant responsible parties.

The operations and maintenance manuals are to be submitted to ABS for reference purposes.

1 Plans and Data to be Submitted

Plans and specifications covering the ship arrangements and general systems listed below are, as applicable, to be submitted:

- i)* Risk assessment (see Subsection 3/2 below)
- ii)* General arrangement of the OCCS components indicating the location and layout onboard
- iii)* Details of OCCS system
 - a)* EGC Pre-scrubbing/quenching and absorber systems
 - b)* CO₂ separation arrangements including desorbers or stripping systems and associated auxiliary equipment
 - c)* Compression, refrigeration, and liquefaction systems
- iv)* CO₂ or carbon compound disposal and/or storage arrangements
- v)* Vent mast and venting arrangements for the CO₂ storage system
- vi)* Control and monitoring, safety shutdown, gas detection and emissions monitoring systems
- vii)* Operations and maintenance manuals (to be submitted for reference purposes)
- viii)* For existing vessels, documentation related to weights and centers calculations due to OCCS retrofit is to be submitted

2 Risk Assessment

- i)* A risk assessment is to be conducted to mitigate all probable risks arising from the use of OCCS systems affecting persons on board, the environment, and the structural strength and integrity of the ship. Consideration is to be given to the hazards associated with physical layout, operation, and maintenance following any reasonably foreseeable failure.
- ii)* The risks are to be analyzed using acceptable and recognized risk analysis techniques. Loss of function, component damage, chemical risk assessment, asphyxiation, toxicity, fire, explosion, and electric shock are to be considered, as a minimum. The analysis is to ensure that risks are eliminated wherever possible. Risks which cannot be eliminated are to be mitigated as far as possible. Details of risks, and the means by which they are mitigated, are to be documented to the satisfaction of ABS.

Further guidance on risk assessment can be found in the *ABS Guidance Notes on Risk Assessment Applications for the Marine and Offshore Industries*.

- iii)* The risk assessment plan is to be developed and submitted to ABS for review and is to contain, but is not limited to:

- a)* Description of proposed function
- b)* Quantitative or Qualitative risk assessment method(s) to be used and description if using a nonstandard method
- c)* Scope and objectives of the assessment
- d)* Subject matter experts / participants / risk analysts, including their background and area of expertise
- e)* Proposed risk acceptance criteria or risk matrix
The risk control and management measures are to be maintained throughout the life of the vessel. Any modification is to be documented and submitted to ABS.
- iv)* In addition to the general risks detailed in 3/2ii), the risk assessment is to specifically consider, but is not limited to:
 - a)* Location and impacts of the OCCS EGC pre-scrubbing/quenching and absorber units – see 3/4.1.
 - b)* Location and impacts of the OCCS desorber or stripping units – see 3/4.2.
 - c)* Location and impacts of the OCCS chemicals, solvents, or consumables – see 3/4.3 and 4/4.3.1.
 - d)* Location and impacts of the CO₂ processing equipment – see 3/4.5.
 - e)* Location and impacts of the CO₂ storage tanks or carbon compound disposal and/or storage tanks and unloading arrangements – see 3/4.6 and 6/6i).
 - f)* Required type and number of personal safety and PPE equipment, together with number and location of eyewash and decontamination showers, as applicable to the specific OCCS system and installation arrangements – see Subsection 3/5.

3 System Configuration and Vessel Integration

3.1 EGC Compatibility and Exhaust Bypass

- i)* Installation and operation of an OCCS EGC system is to be compatible with the fuel oil combustion unit(s) and not to cause any adverse effects on the performance, such as excessive back pressures or high temperatures during operation.
- ii)* The exhaust systems from multiple fuel oil combustion units may be led to a common OCCS system.

Normally, exhaust pipes from internal combustion engines and flue gas pipes from oil-fired boilers are routed separately and are not to be interconnected. However, interconnected exhaust piping systems to a common OCCS EGC unit may be accepted subject to the arrangements preventing the passage or leakage of exhaust gases to other equipment or spaces that may then pose a safety risk to that equipment or health risk to the vessel's crew or passengers. The return of exhaust gas between a running fuel oil combustion unit to another stopped, or in operation, unit is to be prevented. In case of dual fuel and/or gas only internal combustion engines which are required to have their own independent exhaust piping, they may be designed to have a common OCCS EGC unit subject to Flag Administration acceptance.

- iii)* Details are to be submitted demonstrating the exhaust flow compatibility of the EGC parts of the OCCS system with the connected fuel oil combustion unit(s) over the whole operational range of the fuel oil combustion units. This data is to demonstrate that the operating parameters of the fuel oil burning units do not exceed the approved design limits with the EGC parts of the OCCS system in operation.

Where the exhaust systems from multiple fuel oil combustion units are led to a common OCCS EGC unit, the compatibility evaluation is to show that the EGC unit is capable of accommodating the maximum combined exhaust flows of all the connected fuel oil burning equipment for the worst-case scenario for that particular arrangement and operational profile. Consideration will be given to those EGC units that incorporate extractive exhaust fans to maintain the fuel oil combustion unit operating parameters within the approved design limits. See also 3/3.1v).

Commentary:

It is to be noted that OCCS EGC systems that cause diesel engines to operate outside the exhaust backpressure limits detailed in the approved IMO MARPOL Annex VI Regulation 13 NO_x Technical Files may invalidate the emissions certification and will require a re-approval of the engine NO_x certification by the Administration or Recognized Organization responsible for the original certification.

End of Commentary

- iv) OCCS systems are to be designed to enable continued operation of the fuel oil combustion unit(s) at the times the EGC parts of the OCCS system are not in operation, either through operational selection, equipment failure, or system deterioration through partial blocking/clogging.
- v) To avoid any adverse effects on the performance of fuel oil combustion units, such as excessive back pressures or high temperatures, the EGC parts of OCCS systems may be arranged with additional features such as extractive ventilation fans to mitigate such effects.

Where extractive ventilation fans are required to avoid any adverse effects on the performance of fuel oil combustion units, and the system is arranged without an EGC system exhaust gas bypass where such failure of installed exhaust gas extractive fan causes excessive back pressure, the number and capacity of the ventilation fans is to be such that if one fan or a group of fans with a common circuit from the main switchboard or emergency switchboard are out of service, the capacity of the remaining ventilation fan(s) is not less than 100% of the total required.

- vi) An EGC unit fitted to a vessel with a single main propulsion engine is to be installed with an exhaust bypass arrangement, unless arranged for unrestricted flow of exhaust gas and with no risk of causing failure of the main propulsion engine.

The bypass of the EGC unit is to be arranged for automatic operation when the operation of the engine may be affected by back pressure of the EGC system causing possible shutdown of the EGC unit or reduction in the engine power rating.

- vii) Where OCCS EGC units serve multiple fuel oil combustion units, they are to be provided with an exhaust gas bypass unless arrangements are provided to maintain the function of the fuel oil combustion units in the case an EGC unit is out of service and to prevent the return of exhaust gas to an idle engine or fuel oil-fired boiler.
- viii) Where OCCS EGC units incorporate a wet washwater scrubbing process, they are to be capable of being operated without the washwater system in operation, without sustaining thermal damage, or are to be installed with an exhaust bypass arrangement or changeover system to enable continued operation of the fuel oil combustion units in the event the EGC washwater system is not in operation, either through operational selection or equipment failure. As applicable, evidence of material suitability is to be submitted to ABS for dry running of the EGC unit.
- ix) For OCCS EGC units that incorporate a wet washwater scrubbing process, arrangements are to be provided to prevent the ingress of washwater into the fuel oil combustion unit under any circumstance. In general, the design of the inlet exhaust piping is to be arranged to prevent direct the free flow of washwater back to the fuel oil combustion units.

Monitoring, alarm, and shutdown arrangements are to be provided to prevent an abnormal rise of washwater level in the EGC unit reaction chamber.

3.2 Redundancy

Redundancy of equipment, typically providing 100% capacity, is to be provided for those rotating and reciprocating components that form part of the OCCS ancillary systems, such as pumps, fans, and compressors. See also 3/3.1v), 3/3.3, 4/3.1ii) and 4/3.4.3.

Consideration will be given to alternative means of compliance or operation to meet this objective on a case-by-case basis. As applicable, documentation is to be submitted to ABS demonstrating that the reliability of the system or component provides continued serviceability of the OCCS system, or the alternative means of operation provides continued compliance or intent of carbon capture as designed without compromising the vessel's propulsion and maneuvering capability. The carriage of sufficient spare parts onboard is an example of vessel specific arrangements that may be considered by ABS as meeting this objective and is to be justified with reference to the FMEA required by 7/3ii).

3.3 Essential Services

For the purposes of design, construction, testing, and survey, OCCS units and associated components and systems are considered secondary essential services in accordance with 4-8-1/7.3.3 of the *Marine Vessel Rules*. However, cooling and reliquefaction equipment and systems essential to maintain the stored CO₂ temperature and pressure within design limits are considered primary essential services.

3.4 Inclinations

OCCS systems are to be designed for proper operation at the inclination requirements of 4-1-1/7.9 of the *Marine Vessel Rules*.

3.5 Vibration

OCCS systems are to be designed and installed to avoid the presence of dangerous or detrimental vibration that reduce the safety and reliability of the installed equipment or pose a hazard to the vessel or crew. Installed equipment is to be verified to confirm that the limits do not exceed those proposed by the manufacturer. See 4-1-1/7 of the *Marine Vessel Rules*.

3.6 Vessel Stability, Loading and Capacity

- i) For those existing vessels fitting an OCCS system as a retrofit conversion, a revision of the stability and loading calculations may be required based on the additional weights of the OCCS system and increased wind profile together with the weights and capacities of the captured CO₂ and OCCS process consumables.

Commentary:

If the change in lightship displacement from the addition of the OCCS system and all other changes to the vessel subsequent to the most recent approved lightship data, exceeds 2% and/or the change in lightship Longitudinal Center of Gravity (LCG) exceeds 1.0% of the Length Between Perpendiculars (LBP), and/or the lightship Vertical Center of Gravity (VCG) exceeds 1% of the approved value, a stability test will be required for the vessel and the stability documentation will need to be revised to indicate the new lightship values. Where the lightship change is within these limits, the update of the stability documentation is to be in accordance with MSC.429(98)/Rev.1. The stability documentation referred to above includes, but is not limited to, the approved stability book, computer software for onboard calculation of stability, the approved strength book, and the loading instrument.

End of Commentary

- ii) Documentation detailing the effect on Load Line and Stability, capacity plans, loading calculations, and as applicable the computer-based loading instrument, of the installed OCCS systems, captured CO₂ and OCCS process consumables, in accordance with 3/3.6i) above is to be submitted.

4 OCCS System Location

4.1 EGC Pre-Scrubbing/Quenching and Absorber Units

- i) The pre-scrubbing/quenching and absorber EGC units of an OCCS system may be located on deck or within the funnel area typically utilized for engine room exhaust gas silencers and piping.
- ii) The location of pre-scrubbing/quenching or absorber EGC units is to be considered by the risk assessment found in Subsection 3/2. The risk assessment is to consider, but is not limited to, consequences of exhaust and process media leakage, such as washwater or solvents, to those locations together with impacts on normal operations, line of sight and emergency access to life saving appliances (LSA) equipment or escape routes

The risk assessment is to consider any potential hazardous, toxic, or environmentally damaging pollutants that may be introduced to exhaust gases by the specific OCCS system design, and to consider the impacts on normal operation and risk to the crew and the environment of such releases in normal and emergency operation modes.

- iii) See also Section 4 for the requirements for pre-scrubbing/quenching and absorber systems.

4.2 Desorber or Stripping Units

- i) The desorber or stripping units of an OCCS system, together with separators, dryers, and other auxiliary equipment may be located on deck, within dedicated modules or spaces, or within the funnel area typically utilized for engine room exhaust gas silencers and piping.
- ii) The location of desorber or stripping units and associated auxiliary equipment is to be considered by the risk assessment required by Subsection 3/2. The risk assessment is to consider, but is not limited to, consequences of process media and gas leakage to those locations, together with impacts on normal operations, line of sight and emergency access to LSA equipment or escape routes.
- iii) See also Section 4 for the requirements for desorber systems.

4.3 Solvents and Consumables

- i) Locations of any chemicals, solvents, consumables, or process fluids used in the washwater, or CO₂ separation systems are to be based on the hazards of the specific media, required quantities for the installed arrangements and vessel operational profile.
- ii) These CO₂ separation media are to be considered by the risk assessment required by Subsection 3/2. The risk assessment is to consider, but is not limited to, consequences of process media leakage to the storage and processing locations, together with impacts on normal operations and emergency access to LSA equipment or escape routes.
- iii) See also 4/4.3 for the requirements for chemical treatment piping systems.

4.4 EGC Residues

- i) The residues generated from the EGC parts of the OCCS system are to be stored in a designated residue tank, separate from the engine room sludge tank, and arranged for discharge to appropriate shore reception facilities, in accordance with 4-6-4/5.7.4 of the *Marine Vessel Rules*.
- ii) See also 4/4.4 for the requirements for the EGC residue system.

4.5 CO₂ Processing

- i) Equipment for CO₂ gas liquefaction, e.g., compressors, coolers, separators, and dryers is to be located in a dedicated space or compartment.
- ii) The location of the CO₂ processing system and associated auxiliary equipment is to be considered by the risk assessment required by Subsection 3/2. The risk assessment is to consider, but is not limited to, consequences of CO₂ and process media leakages to those locations, together with

impacts on normal operations, line of sight and emergency access to LSA equipment or escape routes.

- iii)* See also Section 5 for the requirements for CO₂ compression, refrigeration, and liquefaction systems.

4.6 Liquefied CO₂ Storage Tanks

- i)* Liquefied CO₂ storage tanks may be located on deck or within dedicated CO₂ tank rooms or hold spaces within the vessel.
- ii)* The CO₂ storage tank(s) are to be located in such a way that the probability of the tanks being damaged following a collision or grounding is reduced to a minimum taking into account the safe operation of the vessel and other hazards that may be relevant to the vessel.
- iii)* The location of the CO₂ storage tanks and unloading arrangements is to be considered by the risk assessment required by Subsection 3/2. The risk assessment is to consider, but is not limited to, consequences of CO₂ release, together with impacts on normal operations, line of sight and emergency access to LSA equipment or escape routes.
- iv)* See also Section 6 for the requirements for CO₂ storage.

5 Personal Safety and PPE

- i)* Suitable protective equipment is to be provided for protection of crew members engaged in normal OCCS system maintenance and operation.
- ii)* The extent of required PPE is dependent on the chemicals, solvents, process media, and other risks such as temperatures/pressures and toxicity or asphyxiation risks of CO₂ releases that the crew may be exposed to during normal operation and routine maintenance of the OCCS equipment and systems. Such equipment may include personal gas/CO₂/oxygen detectors, suitable eye protection, aprons, rubber gloves, coveralls, footwear, air sets, eye wash and shower facilities. The extent and quantities of required personal safety and PPE equipment is to be appropriate for the number of personnel engaged in regular handling operations or that may be exposed in the event of a failure. The extent and numbers of required personal safety and PPE equipment is to be considered by the risk assessment provided in Subsection 3/2.
- iii)* The personal protective and safety equipment required by the risk assessment for the specific vessel and OCCS system is to be kept in suitable, clearly marked lockers located in readily accessible locations.
- iv)* Eyewash and decontamination safety showers are to be provided for hazardous chemicals, solvents, and process media utilized in the OCCS systems that the particular chemical SDS requires rinsing by water in the event of exposure. The location and number of these eyewash stations and safety showers are to be derived from the detailed installation arrangements. As a minimum, the following stations are to be provided:
 - a)* In the vicinity of any spaces containing hazardous chemical process media utilized in the OCCS systems. If there are multiple locations for such spaces on the same deck, then one eyewash and safety shower station may be considered acceptable provided that the station is easily accessible from all such locations on the same deck.
 - b)* As applicable, in the vicinity of any hazardous chemical loading stations. If the loading stations are located on both port and starboard sides, then consideration is to be given to providing two eyewash and safety showers, one on each side.
 - c)* An eyewash station and safety shower is to be provided in the vicinity of any part of the hazardous chemical process systems where there is the potential for contact with the chemicals e.g., openings such as filling/drainage or system connections/components that require periodic maintenance.
 - d)* The eyewash stations and decontamination showers are to be operable in all ambient conditions.

Commentary:

For vessels of unrestricted service, ambient temperature as indicated in 4-1-1/9 TABLE 8 of the *Marine Vessel Rules* is to be considered in the selection and installation of machinery, equipment, and appliances. For vessels of restricted or special service, the ambient temperature appropriate to the special nature is to be considered.

End of Commentary

6 Inspection and Maintenance

OCCS equipment and systems are to be arranged for easy inspection and maintenance. Pre-scrubbing/quenching, absorber and desorber/stripping units are to be arranged with at least one inspection port or hatch available for internal inspection of the main chamber(s), and where applicable the ability to replace internal components is to be provided.

Pre-Scrubbing/Quenching, Absorber and Desorber Systems

1 General

This Section provides requirements on the arrangements and system design for the EGC and CO₂ stripping parts of a post-combustion OCCS system covering the pre-scrubbing/quenching, absorber and desorber units. Where a pre-scrubbing or quenching unit is also designed for the removal of SO_x emissions, that unit may be assigned the additional **EGC-SO_x** notation when it has also been verified to be designed, constructed, and tested in accordance with the requirements of Part 6, Chapter 3 of the *Marine Vessel Rules*.

Where other EEA equipment such as Diesel Particulate Filters, and Electrostatic Precipitators are utilized independently or in combination with OCCS systems, or where alternative means of CO₂ removal and storage such as membrane, cryogenic distillation or dry compound storage systems are applied, then the applicable requirements will vary on a case-by-case basis. However, the intention is not to hinder application of any novel technologies or systems not prescriptively detailed herein, or in Part 6, Chapter 3 of the *Marine Vessel Rules*. Such arrangements will be accepted subject to the arrangements being determined by ABS as being not less effective than the overall safety, strength, goals, principles and intent of the requirements of this document.

Commentary:

At present there are no IMO air pollution requirements directly applicable to OCCS systems under MARPOL Annex VI. However, IMO's latest guidelines for Exhaust Gas Cleaning Systems (EGCS), Resolution MEPC.340(77), the *2021 Guidelines for Exhaust Gas Cleaning Systems*, were adopted 26 November 2021. These guidelines are focused on application to wet scrubbing systems applied for SO_x scrubbing as an equivalent under Regulation 4 for the fuel sulphur limits given by Regulation 14 of MARPOL Annex VI. Where OCCS EGC units are designed for the removal of SO_x emissions, they will need to also comply with those statutory requirements.

Furthermore, many of the principles established for testing, survey, and certification of EGCS units within the IMO guidelines, including discharge water quality, may also be interpreted as applicable to EGCS in general. Therefore, dialogue with the flag Administration is recommended to determine if any of the air, or water, quality criteria, documentation, monitoring, survey, or certification requirements of the IMO EGCS guidelines may be interpreted as applicable to OCCS EGC and CO₂ stripping systems.

It is also recommended to clarify requirements with flag and port Administrations on 'open loop' discharges, as may be applicable to pre-scrubbing/quenching units, and specifically allowable discharges in ports, harbors and estuaries. With regard thereto, note that IMO Resolution MEPC.307(73), the *2018 Guidelines for the Discharge of Exhaust Gas Recirculation (EGR) Bleed-Off Water*, adopted 26 October 2018, provides guidance on water discharge quality when using sulfur compliant fuel.

It is understood that the majority of post-combustion OCCS systems will utilize 'closed loop' washwater and solvent systems, however, IMO requires risk and impact assessments of discharge water from EGCS, to protect sensitive waters and

environments from EGCS discharges to water. As above, and as applicable to the specific OCCS design, dialogue with the flag and port Administrations is recommended to determine if any of the risk and impact assessment criteria may be applicable to any OCCS EGC and CO₂ stripping systems (open or closed loop) that are designed with bleed or discharge water arrangements.

End of Commentary

2 Plans and Data to be Submitted

Plans and specifications covering the EGC pre-scrubbing/quenching, absorber and desorber units are, as applicable, to be submitted:

- i)* General arrangement of the pre-scrubbing/quenching, absorber and desorber installation, layout, and systems.
- ii)* Documentation detailing the pre-scrubbing/quenching, absorber and desorber specifications.
- iii)* Analyses demonstrating compatibility of the EGC pre-scrubbing/quenching and absorber units with the fuel oil combustion units - see 3/3.1.
- iv)* Hull plans showing the foundation and attachments to the vessel's structure, including scantlings, welding details, and foundation details of principal components.
- v)* Documentation detailing the effect on Load Line and Stability and loading of the pre-scrubbing/quenching, absorber and desorber systems - see 3/3.6.
- vi)* Material specifications for the pre-scrubbing/quenching, absorber and desorber units, pumps, valves, storage/process tanks, residue tanks, piping, distribution systems, separators, and associated components, including a corrosion assessment detailing the corrosive effect of system liquids, vapors, and gases on the materials used in the EGC and CO₂ stripping parts of the OCCS system.
- vii)* Arrangement and capacity of tanks for storage of chemicals, solvents, process washwater, EGC and process residues.
- viii)* Details of all piping systems, including details of piping and associated components, design pressures, temperatures, insulation, and drip trays.
- ix)* Descriptions and schematic diagrams for the control and monitoring systems, including set points for abnormal conditions and details of the location and positions where exhaust emission monitoring and washwater or process media monitoring systems are to be located.
- x)* Details of all electrical equipment installed for the pre-scrubbing/quenching, absorber and desorber unit(s) and associated systems, including computer-based systems.
- xi)* Failure Modes and Effects Analysis (FMEA) to determine possible failures and their effects in the safe operation of the pre-scrubbing/quenching, absorber and desorber unit(s). See 7/3ii).
- xii)* Emergency shutdown arrangements.
- xiii)* Operating and maintenance instruction manuals, including SDS sheets and details for handling of hazardous and non-hazardous chemicals used in the pre-scrubbing/quenching, absorber and desorber system (to be submitted for reference purposes only).
- xiv)* Testing procedures during installation and commissioning trials (to be submitted for Survey verification only).

3 Pre-Scrubbing/Quenching, Absorber and Desorber System Equipment

3.1 Pumps/Fans

- i)* Where provided, OCCS pre-scrubbing/quenching, absorber and desorber unit(s) utilizing washwater, circulation, solvent, discharge, and pumps essential for the continual operation of the

OCCS systems, are to be tested and certified in accordance with 4-6-1/7.3 of the *Marine Vessel Rules*. This is applicable to OCCS EGC systems connected to fuel oil combustion units with total rated at 2250 kW and above or internal combustion engines having cylinders of more than 300 mm (11.8 in.) bore.

- ii) Unless alternative means of compliance in accordance with 3/3.2 are applicable, redundant washwater, circulation, solvent, discharge, and pumps essential for the continual operation of the OCCS systems, are to be provided. There are to be at least two of these essential pumps, and the capacity of the pumps, with any one pump out of service, is to be sufficient for continuous operation of the OCCS systems at full rating. See also 4/3.4.3.

For vessels fitted with two or more identical OCCS systems, the provision of a common standby pump (for each essential system) capable of serving all OCCS units will suffice rather than providing individual standby pumps for each OCCS EGC unit.

- iii) Unless alternative means of compliance in accordance with 3/3.2 are applicable, and where exhaust fans form part of the OCCS EGC system and are essential for continual operation of the EGC system at full rating, such fans are to be installed in a redundant arrangement. The number and power of the fans are to be such that if one fan, or a group of fans, is out of service, the capacity of the remaining fan(s) is not to be less than 100% of the total required – see also 3/3.1v).

3.2 Exhaust Heat Exchangers

Where provided, exhaust gas economizers, heat exchangers and/or exhaust plume heaters incorporated within the OCCS EGC system are to be designed, constructed, and certified in accordance with Section 4-4-1 of the *Marine Vessel Rules*.

3.3 Process Pressure Vessels and Heat Exchangers

All process pressure vessels and heat exchangers, including pre-scrubbing/quenching, absorber, desorber, separation unit(s), filters, dryers, etc., incorporated within the OCCS EGC and CO₂ stripping systems, and within the scope of 4-4-1/1.1 of the *Marine Vessel Rules*, are to be designed, constructed, and certified in accordance with Section 4-4-1 of the *Marine Vessel Rules*.

3.4 Electrical System

The electrical system and electrical equipment requirements in this subsection are to be applied in association with the requirements of Part 4, Chapter 8 of the *Marine Vessel Rules*.

3.4.1 Electrical Motors and Controllers

Motors and motor controllers of 100 kW (135 hp) and over are to be certified in accordance with Part 4, Chapter 8 of the *Marine Vessel Rules*.

3.4.2 Electrical Load Analysis

- i) The number and capacity of generators are to be sufficient under normal seagoing conditions with one generator in reserve to carry those loads for essential services and for minimum comfortable conditions of habitability as per 4-8-2/3.1.1 of the *Marine Vessel Rules*.
- ii) The electrical loads associated with the OCCS systems are to be included in the electric-plant load analysis required by 4-8-1/5.1.5 of the *Marine Vessel Rules*.

3.4.3 Standby Pump/Fan Arrangements

- i) In the event of failure of the essential OCCS system pumps or fans, the standby pump or fan required by 4/3.1, where provided, is to be automatically started and put into service. This failure is to be alarmed at the local and remote-control station(s), as applicable.
- ii) Where provided, each standby pump or fan is to be fed from separate sections of the switchboard such that in the event of failure of one section of the switchboard the standby pump or fan may be fed from the other separate section of the switchboard.

3.4.4 Circuit Protection Devices and Compatibility

Circuit breakers are to be installed for miscellaneous OCCS system electrical loads and are to be compatible with the prospective short circuit current level calculated at the switchboards.

4 Pre-Scrubbing/Quenching, Absorber and Desorber System Piping

4.1 Exhaust Gas Piping Systems

4.1.1 Exhaust Gas Piping and OCCS Unit Materials and Installation

- i) Exhaust gas piping materials located before the OCCS EGC units may be of the same material specification as the standard exhaust piping.
- ii) The sections of the pre-scrubbing/quenching, absorber and desorber units that are subjected to washwater or solvent media (e.g., the interior reaction chamber or piping/nozzles, etc.) are to be constructed of suitable corrosion resistant materials.
- iii) Exhaust gas piping materials used after the OCCS EGC units are to be of a corrosion resistant material appropriate for the environment such as stainless steel.
- iv) The exhaust piping systems for OCCS EGC systems are to meet the applicable requirements of 4-6-2/9 and 4-6-5/11 of the *Marine Vessel Rules*.
- v) Exhaust gas piping and piping components constructed of non-metallic materials are to comply with Section 4-6-3 of the *Marine Vessel Rules* and are to be specifically approved for the intended application.

4.1.2 Exhaust Gas Piping Valves

- i) Valves used in the exhaust gas parts of OCCS EGC systems are to meet the requirements of 4-6-2/5.11 of the *Marine Vessel Rules* and, in general, are to comply with a recognized standard and are to be permanently marked in accordance with the requirements of that standard.

The valves located after the EGC units are to be constructed of corrosion resistant materials.

- ii) Isolation and bypass valves used in OCCS EGC exhaust piping systems are to prevent the passage of exhaust gases to other fuel oil combustion units or machinery spaces.

Where bypass arrangements for the OCCS EGC units are provided, the isolation and bypass valves are to be arranged in an interlocked, fail-safe manner, such that free flow of exhaust gases to the atmosphere is possible at all times, either through the OCCS EGC units or through the bypass. Bypass valves are to be provided with a local position indicator.

- iii) Valves are to be installed in accessible locations, clear of or protected from obstructions, moving equipment, and hot surfaces, in order to permit regular inspection and/or periodic servicing.
- iv) Upon loss of control power, remotely controlled valves are to remain in the last ordered position, provided there is a readily accessible means to manually close the valves, or are to fail safe in accordance with the FMEA required by 7/3ii).
- v) Remotely controlled valves are to be clearly identified and are to be provided with position indicators at the local and OCCS system remote-control station, as applicable.

4.1.3 Interconnections of Exhaust Gas Piping

- i) Where the exhaust piping systems from multiple fuel oil combustion units lead to a common OCCS EGC system, they are to be arranged in accordance with 3/3.1ii) and iii).
- ii) In all arrangements, the OCCS EGC system is to be designed so as to not exceed the backpressure limits specified by the connected engine or boilers. Where extractive fans are installed to mitigate such effects, they are to be arranged in accordance with 3/3.1v) and 4/3.1iii).

4.1.4 Exhaust Gas Piping and OCCS Unit Insulation

Hot surfaces of exhaust gas piping and OCCS units, or their associated equipment or systems, likely to come into contact with the crew during operation are to be suitably guarded or insulated. Where the surface temperatures are likely to exceed 220°C (428°F) and where any leakage, under pressure or otherwise, of fuel oil, lubricating oil, or other flammable liquid is likely to come into contact with the exhaust pipes or OCCS units, these surfaces are to be suitably insulated with noncombustible materials that are impervious to such liquids. Insulation material not impervious to oil is to be encased in sheet metal cladding or an equivalent impervious sheath.

4.2 Pre-scrubbing/Quenching Washwater Piping

4.2.1 Piping and Connections

- i)* In general, pipe fittings and joints are to meet the requirements of the *Marine Vessel Rules* for certification in 4-6-1/7.1, materials in 4-6-2/3, and design in 4-6-2/5.5 and 4-6-2/5.15, subject to the limitations found in 4-6-5/7.3.3 TABLE 3.

Molded non-metallic expansion joints, where used, are to be of an approved type (see 4-6-2/5.8.1, 4-6-2/9.19 TABLE 2 of the *Marine Vessel Rules* for Cu and Cu Alloy and 4-6-2/9.19 TABLE 5A of the *Marine Vessel Rules* for pipe thickness).

- ii)* The piping material for the corrosive pre-scrubbing/quenching and washwater piping systems is to be selected based on the corrosive nature of the liquid media.
- iii)* Pipes and piping components made of thermoplastic or thermosetting plastic materials, with or without reinforcement, may be used in piping systems subject to compliance with the requirements of Section 4-6-3 of the *Marine Vessel Rules*. For the purpose of these Rules, “plastic” means both thermoplastic and thermosetting plastic materials, with or without reinforcement, such as polyvinyl chloride (PVC) and fiber reinforced plastics (FRP). Plastic washwater piping is to meet Level 3 fire endurance testing requirements (see 4-6-3/5.11 of the *Marine Vessel Rules*).
- iv)* Flexible hoses are to comply with the requirements of 4-6-2/5.7 of the *Marine Vessel Rules*.

4.2.2 Remote Control Valves

- i)* Upon loss of control power, remotely controlled valves are to remain in the last ordered position, provided there is a readily accessible means to manually close the valves, or are to fail safe in accordance with the FMEA required by 7/3ii).
- ii)* Remotely controlled valves are to be clearly identified and are to be provided with position indicators at the local and OCCS system remote-control station, as applicable.
- iii)* Valves are to be installed in accessible locations, clear of or protected from obstructions, moving equipment, and hot surfaces to permit regular inspection and periodic servicing.

4.2.3 Overboard Discharges

- i)* Overboard discharges (e.g., treated wash water) from any OCCS systems are not to be interconnected to other systems.
- ii)* Special attention is to be paid to the corrosion resistivity of OCCS EGC pre-scrubbing/quenching washwater overboard discharge piping. The distance piece between the discharge valve and the shell plating is to comply with 4-6-2/9.13.3 of the *Marine Vessel Rules* and also be fitted internally with high -corrosive-resistance protection material such as super duplex stainless steel sleeves. Otherwise, the distance piece is to be at least of Sch.160 construction and is to be protected with an anti-corrosive coating (e.g., epoxy) suitable for the washwater discharges. Evidence of suitability for the protection means is to be submitted. Alternative arrangements shown to be of not less effective construction may be considered by ABS on a case-by-case basis. Where

applicable, adequate arrangements are to be provided to prevent galvanic corrosion due to the use of dissimilar metals. In such cases where a galvanic couple cannot be avoided, consideration may be given to coating the stainless steel or to using a more noble steel grade.

- iii) Due consideration is to be given to the location of overboard discharges with respect to vessel sea chest inlets, propulsion features such as thrusters and propellers, or to prevent any discharge of water onto survival craft during abandonment.
- iv) Where plastic pipes are permitted to be used for the OCCS pre-scrubbing/quenching washwater supply and discharge lines, the valves installed on the shell and the pipe connection to the shell are to be composed of metallic materials. The side shell valves are to be arranged for remote control from outside the space in which the valves are located. Materials used for the control system within the space are to be heat resistant. See 4-6-3/7.9 of the *Marine Vessel Rules*.

4.3 Chemical Treatment Systems

4.3.1 General

The specific chemicals, solvents and process media used in OCCS pre-scrubbing/quenching, absorber and desorber systems will vary dependent on the particular design. Accordingly, the requirements for installation will be determined by ABS on a case-by-case basis and are to be considered by the risk assessment required by Subsection 3/2. The risk assessment is to consider any additional gaseous products, chemicals or discharges that may be introduced to the exhaust gas stream, or overboard discharges, during normal operation and failure of the OCCS system.

For systems utilizing Caustic Soda (Sodium Hydroxide, NaOH) in closed loop pre-scrubbing/quenching or SO_x scrubbing units, the requirements of 6-3-2/11.5 of the *Marine Vessel Rules* are applicable.

If other hazardous chemicals, such as amine solvents, are used in OCCS absorber, desorber or processing systems, the arrangements are to be consistent with the intent of the requirements for NaOH, and are to cover the following main components and systems, as applicable:

- Piping and tank materials
- Bulk loading and arrangements
- Arrangement of tanks
- Tank filling, vents and overflow arrangements
- Sounding and temperature indication
- Spill trays
- Ventilation arrangements
- Unloading arrangements for residues, spent solvents or solvents intended for onshore processing
- PPE – see Subsection 3/5

Where spent solvents are retained onboard for subsequent processing ashore, or where the carbon removal processes store the carbon in different compounds, the storage details are to be submitted to ABS to determine if storage is in accordance with these requirements, as applicable to the particular chemical hazards.

4.3.2 Safety Notices

Safety instructions relating to precautions and corrective response actions are to be posted in the compartment or spaces containing hazardous OCCS system chemicals, and beside the entrance to the compartment or space. Detailed guidelines given in the SDS are to be followed.

4.4 Residue System

- i) CO₂ capture and stripping process residues generated from the OCCS are to be stored in a designated residue tank, separate from the engine room sludge tank, and arranged for discharge to appropriate shore reception facilities, in accordance with 4-6-4/5.7.4 of the *Marine Vessel Rules*. Such residues are not to be discharged to the sea or incinerated on board.

The residue tanks are to be designed to facilitate cleaning.

- ii) The material of the residue tanks is to be selected based on the corrosive nature of the residue.
- iii) The capacity of the residue tanks is to be based on the expected residue volumes applicable to the number and type of installed OCCS EGC systems and the maximum period of voyage between ports where residues can be discharged. In the absence of precise data, an interval of 30 days is to be used with engines running at normal continuous cruising speed.
- iv) The residue tanks are to be provided with vent pipes complying with 4-6-4/9 of the *Marine Vessel Rules*. Vents are not to be subjected to deterioration due to the concentrations involved, and the arrangement is to be such that the potential source of moisture from the vents does not present any danger to the crew or vessel. Alternatively, the tanks are to be fitted with appropriately sized pressure/vacuum valves.
- v) The residue tanks are to be arranged with a high-level alarm.
- vi) Sounding arrangements are to be provided for the residue tanks in accordance with 4-6-4/11.3.7 of the *Marine Vessel Rules*. In addition to local level gauging, residue tanks are to have remote level gauging indication at the control station.
- vii) For those vessels that do not utilize onboard incineration and collect all engine room sludge for disposal ashore, ABS will consider arrangements utilizing a combined engine room sludge and OCCS residue tank, provided the tank meets the requirements of 4/4.4i) through vi), the EGC residue and oil record logs satisfy any statutory requirements that may be applicable, e.g. MEPC.340(77), and the residues are disposed at MARPOL reception facilities.

Combined engine room sludge and OCCS residue tanks are to be sized to provide adequate capacity based on the sludge tank capacity requirements of 4-6-4/5.7.3 of the *Marine Vessel Rules* plus the capacity requirements for residue tanks of 4/4.4.iii).

4.5 Ancillary Systems

Where cooling/heating ancillary systems are utilized in OCCS pre-scrubbing/quenching, absorber or desorber systems, those systems are to be arranged as follows:

- i) Redundancy of equipment is to be provided for those rotating and reciprocating components that form part of the OCCS ancillary systems in accordance with 3/3.2 and 3/3.3.
- ii) Piping design and arrangements are to be in accordance with the applicable requirements of Part 4, Chapter 6 of the *Marine Vessel Rules*.

5 Monitoring, Alarm and Control Systems

Automatic control, monitoring, alarm and safety functions are to be provided for the OCCS pre-scrubbing/quenching, absorber and desorber systems in accordance with Section 7.

The monitoring and safety shutdowns are to be in accordance with Section 7, Table 1.

CO₂ Compression, Refrigeration and Liquefaction Systems

1 General

This Section provides the requirements for OCCS systems that remove carbon as CO₂ and covers the machinery and equipment plant for separation, compression, cooling, drying and liquefaction of the CO₂ gas and any liquid cooling or reliquefaction systems used to maintain control of the stored CO₂ temperature and pressure. See Section 6 for the requirements for liquefied CO₂ storage.

This Section is to be applied in association with the applicable requirements of 5C-8 of the *Marine Vessel Rules*, which incorporates the *International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk* (IGC Code), for liquefied gas applications and in particular the special requirements for CO₂ given under 5C-8-17/21 and 5C-8-17/22 of the *Marine Vessel Rules* for high purity and reclaimed quality CO₂ respectively.

The intention is not to hinder application of any novel technologies or systems not prescriptively detailed herein. OCCS systems that remove, process and store carbon in compounds other than CO₂ will also be considered. Such solutions will be considered subject to the arrangements being determined by ABS as being not less effective than the overall safety, strength, goals, principles and intent of the requirements of this document.

2 Plans and Data to be Submitted

Plans and specifications covering the OCCS compression, cooling, drying and liquefaction plant are, as applicable, to be submitted:

- i) General arrangement of the CO₂ gas compression, cooling, drying and liquefaction compartment, layout and systems.
- ii) Documentation detailing the CO₂ gas compression, cooling, drying and liquefaction specifications.
- iii) Schematic diagram of the ventilation system for the CO₂ gas compression, cooling, drying and liquefaction compartment including openings.
- iv) Diagram of the fixed CO₂ and O₂ gas detection and monitoring and alarm systems and associated shut off and shutdown systems.
- v) Details of all piping systems, including details of piping and associated components, design pressures, temperatures and insulation.
- vi) Gas compressors.
- vii) Filters and dryers.
- viii) Pressure vessels, including separators and heat exchangers.
- ix) Schematic diagram of the cooling, refrigeration and liquefaction system(s) together with the calculations concerning the refrigerating and liquefaction capacity.

- x) Descriptions and schematic diagrams for the control and monitoring system including set points for abnormal conditions.
- xi) Details of all electrical equipment in the CO₂ gas compression, cooling, drying and liquefaction compartment.
- xii) Schematic wiring diagrams.
- xiii) Electric bonding (earthing) arrangements.
- xiv) Failure Modes and Effects Analysis (FMEA) to determine possible failures and their effects in the safe operation of the CO₂ gas compression, cooling, drying and liquefaction plant. See 7/3ii).
- xv) Emergency shutdown arrangements.
- xvi) Operating and maintenance instruction manuals (to be submitted for reference purposes only).
- xvii) Testing procedures during installation and commissioning trials (to be submitted for Survey verification only).

3 System Design and Capacity

- i) All of the OCCS compression, cooling, drying, and liquefaction plant is to be located in a dedicated machinery space or compartment meeting the requirements of Subsection 5/4.
- ii) The OCCS compression, cooling, drying, and liquefaction plant is to be designed taking into account the composition of the CO₂ gas stream and expected impurities, including the effect those impurities may have on the “triple point” temperature of the CO₂.

Commentary:

The precise "triple point" temperature of a particular CO₂ gas stream depends on the purity of that CO₂. Refer also to 5C-8-17/21 and 5C-8-17/22 of the *Marine Vessel Rules*.

The quality and purity of the CO₂ processed onboard and landed ashore is a matter of commercial agreement and may be subject to additional processing ashore depending on the intended application. For example, the utilization of captured CO₂ in the food and beverage industries requires that CO₂ meets the applicable national regulations; however, captured CO₂ for sequestration purposes may be of a lower purity. Currently no international CO₂ purity standards for CCS systems exist and guidance may be sought from developing standards such as those from the UK's National Physical Laboratory.

End of Commentary

- iii) The capacity of the cooling or reliquefaction systems required for temperature and pressure control of the stored CO₂ is to be based on the intended CO₂ storage condition and the requirements of Subsection 6/4.
- iv) Cooling or reliquefaction systems are to meet the redundancy requirements of 3/3.2 and are considered primary essential services in accordance with 4-8-1/7.3.3 of the *Marine Vessel Rules*.
- v) The CO₂ gas to liquid process system is to be designed to prevent venting of CO₂ at all times except in emergency situations.
- vi) The procedures for overall operation between dry-dockings of the CO₂ storage tank(s) and associated compression, refrigeration and liquefaction systems, covering but not limited to, cool down, unloading, gas freeing, pressure/temperature control, emergency shutdown, maintenance and inspection are to be included in the operating and maintenance manuals.

4 CO₂ Machinery Space

- i) All of the OCCS compression, cooling, drying and liquefaction plant is to be located in a dedicated gas tight machinery space or compartment with no direct access from accommodation spaces, service spaces or control stations.

- ii) The space is to be arranged to provide access to personnel wearing protective clothing and breathing apparatus, and in the event of injury to allow unconscious personnel to be removed. At least two widely separated escape routes and doors are to be provided. A single escape route may be accepted where the maximum travel distance to the door is 5m or less.
- iii) All emergency shutdown valves are to be readily accessible to personnel wearing protective clothing.
- iv) The space is to be fitted with an independent mechanical extraction ventilation system providing thirty air changes per hour and the space is to be maintained at under pressure relative to adjacent spaces.

Failure of the ventilation system is to give an audible and visual alarm at the remote-control position and at the local control station.

Ventilation suction inlets are to be located as low as practicable in the space considering the density of CO₂.

- v) The CO₂ machinery space, and other enclosed spaces where CO₂ may accumulate, are to be fitted with continuous CO₂ gas detection monitoring for carbon dioxide build up; see also 5C-8-17/21.6 of the *Marine Vessel Rules*.

The placement of the gas detectors is critical to the effectiveness of the gas detection system. The exact location of the gas detectors is to be determined taking consideration the prevailing airflow, sensitivity of the gas detectors and considering the density of CO₂. See also 7/5i) for placement of detectors.

An alarm is to be given at the remote-control position(s) and at the local control station if the CO₂ content rises above 4%. Visual and audible alarms are also to be placed at each entrance to the machinery space.

- vi) A minimum of two oxygen sensors are to be positioned at appropriate locations within the space. See also 7/5i) for placement of detectors.

An alarm is to be given at the remote-control position(s) and at the local control station if the oxygen content is below 19%. Visual and audible alarms are also to be placed at each entrance to the machinery space.

- vii) Where any refrigerants being used are considered to be toxic, an alarm system is to be fitted to detect refrigerant concentration exceeding the time-weighted average to which personnel may be repeatedly exposed in the space.

- viii) Gas detection equipment is to meet the requirements of Subsection 7/5.

- ix) Warning signs are to be placed where they will be easily seen at the entrances to CO₂ machinery spaces, and other enclosed spaces where CO₂ may accumulate, that warn of the risks of asphyxiation.

5 System Equipment

5.1 Reliquefaction and Refrigeration Systems

- i) Reliquefaction and cooling or refrigeration systems are to be designed, constructed, and tested in accordance with the applicable requirements of 5C-8-7/3 and Appendix 5C-8-A5 of the *Marine Vessel Rules*.
- ii) Where the CO₂ cooling or reliquefaction plant is intended to be part of the method of control of tank temperature and pressure, the liquid cooling or reliquefaction plant is to be arranged in accordance with the redundancy requirements of 3/3.2 and availability in accordance with 5C-8-7/8 of the *Marine Vessel Rules*. See also Subsection 6/4 of this document for CO₂ storage tank filling limits and pressure/temperature management criteria.

5.2 Materials

- i) Materials in general are to comply with the requirements of the ABS *Rules for Materials and Welding (Part 2)*.
- ii) Materials for liquefied gases are to comply and be tested and certified in accordance with the applicable requirements of Section 5C-8-6 of the *Marine Vessel Rules*.
- iii) The materials of construction are to take into account the possibility of corrosion from impurities in the gas stream such as water, oxides of sulfur, hydrogen sulfide, and other compounds that may remain from the exhaust gas stream or be introduced as part of the CO₂ cleaning and stripping process. See also 5C-8-17/21.5 and 5C-8-17/22.1 of the *Marine Vessel Rules*.
- iv) All materials used in the liquefied CO₂ piping and equipment are to be suitable for the lowest temperature that may occur in service, which is defined as the saturation temperature of the CO₂ at the set pressure of the automatic safety system described in 6/3.4iv).

5.3 Compressors

Gas compressors are to be designed, constructed, and tested in accordance with 5C-8-5/13.1.4 of the *Marine Vessel Rules*.

Motors and motor controllers of 100 kW (135 hp) and over are to be certified in accordance with Part 4, Chapter 8 of the *Marine Vessel Rules*.

5.4 Separators, Pressure Vessels, and Heat Exchangers

All separators, process pressure vessels, heat exchangers, filters, and dryers within the scope of 4-4-1/1.1 of the *Marine Vessel Rules*, are to be designed, constructed, and certified in accordance with Section 4-4-1 of the *Marine Vessel Rules*.

Liquefied CO₂ pressure vessels are to be designed in accordance with the requirements for Type C independent tanks of Section 5C-8-4 of the *Marine Vessel Rules*.

Further guidance on Type C tanks can be found in the ABS *Guidance Notes on Strength Assessment of Independent Type C Tanks*.

5.5 Pumps

Liquefied CO₂ pumps are to be designed and tested in accordance with 5C-8-5/13.1.3 (IACS) of the *Marine Vessel Rules*.

6 System Piping

- i) Any CO₂ piping is not to pass through accommodation spaces, service spaces or control stations.
- ii) Gaseous and liquified CO₂ piping is to comply with 5C-8-5 of the *Marine Vessel Rules*.
- iii) The piping system is to be of welded construction and flange joints are to be kept to a minimum. Gaskets are to be protected against blow-out.
- iv) Where piping is dismantled regularly, or where liquid leakage may be anticipated such as at flanged joints or valves, spray shields and drip trays are to be provided to protect against the initial liquid leakage. Consideration to the specific release conditions, or phase change to gas or solid, is to be given.
- v) The piping system is to be installed with sufficient flexibility to accommodate the oscillating movements that may be applicable without risk of fatigue failure.

7 Monitoring, Alarm and Control Systems

Automatic control, monitoring, alarm and safety functions are to be provided for the OCCS compression, cooling, drying and liquefaction plant systems in accordance with Section 7.

The monitoring and safety shutdowns are to be in accordance with Section 7, Table 2.

SECTION 6 Liquefied CO₂ Storage

1 General

This Section provides the requirements for OCCS systems that store carbon as liquefied CO₂ and covers the requirements for the CO₂ storage tank(s) and associated pressure relief and venting systems. See Section 5 for the requirements for CO₂ compression, refrigeration, and liquefaction systems.

This Section is to be applied in association with the applicable requirements of 5C-8 of the *Marine Vessel Rules*, which incorporates the *International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk* (IGC Code), for liquefied gas applications and in particular the special requirements for CO₂ given under 5C-8-17/21 and 5C-8-17/22 for high purity and reclaimed quality CO₂ respectively.

The intention is not to hinder application of any novel technologies or systems not prescriptively detailed herein. OCCS systems that remove, process and store carbon in compounds other than CO₂, or store CO₂ in a compressed form will also be considered. Such solutions will be considered subject to the arrangements being determined by ABS as being not less effective than the overall safety, strength, goals, principles and intent of the requirements of this document.

2 Plans and Data to be Submitted

Plans and specifications covering the liquefied CO₂ storage tank(s) with all the accessories are, as applicable, to be submitted:

- i) General arrangement showing the position of the CO₂ storage tank(s), details of manholes and other openings and, as applicable, hold space arrangements.
- ii) Plans of the hull structure in way of the CO₂ storage tank(s), including the installation of attachments, accessories, internal reinforcements, saddles for support and tie-down devices.
- iii) Detailed construction drawings of the CO₂ storage tank including design calculations for the pressure boundary, tank support arrangement and analysis for the load distribution, together with anti-collision, chocking arrangement and design calculations.
- iv) Material specifications for the CO₂ storage tank including attachments, valves, and accessories.
- v) Design loads and structural analyses for the CO₂ storage tank(s) together with complete stress analysis, as applicable, of the hull and CO₂ storage tank(s).
- vi) Specifications and plans of the insulation system and calculation of the heat balance.
- vii) Procedures and calculations of the cooling down operations.
- viii) Details and installation of the safety valves and relevant calculations of their relieving capacity, including back pressure.

- ix) Tank pressure and temperature control calculation including pressure accumulation, as applicable, as required by 6/4iii).
- x) Unloading systems, venting systems, and gas-freeing systems, as well as a schematic diagram of the remote-controlled valve system. As applicable, details to include any unloading manifolds, pipework, valves, couplings, and control stations.
- xi) Details and installation of the various monitoring and control systems, including the devices for measuring the level, temperature, and pressure of the CO₂ in the tanks and set points for abnormal conditions.
- xii) Schematic diagram of the ventilation system indicating the vent pipe sizes and location of the openings.
- xiii) Details of the electrical equipment and of the electrical bonding (earthing) of the CO₂ tanks and piping.
- xiv) Diagram of gas detection systems.
- xv) Schematic wiring diagrams.
- xvi) Welding procedures, stress relieving and non-destructive testing plans.
- xvii) Construction details of submerged pumps including material specifications.
- xviii) Emergency shutdown arrangements.
- xix) Operating and maintenance instruction manuals (to be submitted for reference purposes only).
- xx) Testing procedures during installation and commissioning trials (to be submitted for Survey verification only).

3 Liquefied CO₂ Storage Tanks

3.1 Design

- i) The storage tank(s) used for liquefied CO₂ storage is to be an independent Type C tank designed in accordance with 5C-8-4 of the *Marine Vessel Rules*.
- ii) The CO₂ storage, pressure relief and control and monitoring systems are to be designed taking into account the composition of the liquefied CO₂, water content and expected impurities, including the effect those impurities may have on the "triple point" temperature of the CO₂.

Commentary:

Uncontrolled pressure loss from the CO₂ storage tank can cause dry ice formation and the CO₂ will change from liquid to solid form. The precise "triple point" temperature of a particular CO₂ gas stream will depend on the purity of that CO₂. Refer also to 5C-8-17/21 and 5C-8-17/22 of the *Marine Vessel Rules*.

The quality and purity of the CO₂ processed onboard and landed ashore is a matter of commercial agreement and may be subject to additional processing ashore depending on the intended application. For example, the utilization of captured CO₂ in the food and beverage industries will require that CO₂ meets applicable national regulations; however, captured CO₂ for sequestration purposes may be of a lower purity. Currently no international CO₂ purity standards for CCS systems exist and guidance may be sought from developing standards such as those from the UK's National Physical Laboratory.

End of Commentary

- iii) The CO₂ storage tank(s) and pressure relief systems, together with associated cooling/refrigeration and reliquefaction systems, as applicable, are to be designed to prevent venting of CO₂ at all times, except in emergency situations. See also Subsection 6/4 for CO₂ storage tank filling limits and pressure/temperature management criteria.
- iv) It is to be possible to gas free the CO₂ storage tanks with permanently fitted piping systems.

- v) The procedures for overall operation between dry-dockings of the CO₂ storage tank(s) and associated compression, refrigeration and liquefaction systems, covering but not limited to, cool down, unloading, gas freeing, pressure/temperature control, emergency shutdown, maintenance and inspection are to be included in the operating and maintenance manuals.

3.2 Materials

- i) Materials in general are to comply with the requirements of the ABS *Rules for Materials and Welding (Part 2)*.
- ii) Materials for liquefied gases are to comply and be tested and certified in accordance with the applicable requirements of 5C-8-6 of the *Marine Vessel Rules*.
- iii) The materials of construction are to take into account the possibility of corrosion from impurities in the gas stream such as water, oxides of sulphur, hydrogen sulfide, and other compounds that may remain from the exhaust gas stream or be introduced as part of the CO₂ cleaning and stripping process and which can cause acidic corrosion or other problems. See also 5C-8-17/21.5 and 5C-8-17/22.1 of the *Marine Vessel Rules*.
- iv) All materials used in the liquefied CO₂ storage tank and piping systems are to be suitable for the lowest temperature that may occur in service, which is defined as the saturation temperature of the CO₂ at the set pressure of the automatic safety system described in 6/3.4vi).

3.3 Pressure Relief and Venting System

- i) To protect the CO₂ storage tank(s) from overpressure or under pressure, they are to be provided with pressure relief valves and discharge piping meeting the requirements of 5C-8-8 of the *Marine Vessel Rules*, with the exception of 5C-8-8/2.9.2, 5C-8-8/2.10 and 5C-8-8/2.15 referenced by 6/3.3iii), 6/3.3iv) and 6/3.3v).
- ii) There is a potential for the CO₂ to solidify in the event that a CO₂ tank pressure relief valve fails in the open position. To avoid this, a means of isolating the pressure relief valves is to be provided and the requirements of 5C-8-8/2.9.2 of the *Marine Vessel Rules* do not apply. See also 5C-8-17/21.2 of the *Marine Vessel Rules*.

The CO₂ gas from the protective devices of the tank is to be discharged to a safe location on the open deck that are:

- Not within 3 m (10 ft) of areas traversed by personnel; and
 - Not within 6 m (20 ft) of air intakes for machinery (engines and boilers) and all ventilation inlets/outlets.
- iii) The discharge (venting) piping system from the CO₂ tank pressure relief valves is not required to comply with 5C-8-8/2.10 of the *Marine Vessel Rules* but is to be designed so it remains free from obstructions that could cause clogging. See also 5C-8-17/21.3 of the *Marine Vessel Rules*.
- iv) To avoid clogging, protective screens are not to be fitted to the outlets of the CO₂ tank pressure relief valve discharge piping, hence the requirements of 5C-8-8/2.15 of the *Marine Vessel Rules* are not applicable. See also 5C-8-17/21.2 and 5C-8-17/21.3 of the *Marine Vessel Rules*.

3.4 Instrumentation and Monitoring

- i) The CO₂ storage tank(s) are to be provided with means of indicating level, pressure and temperature in accordance with the applicable requirements of 5C-8-13/1, 5C-8-13/2, 5C-8-13/4 and 5C-8-13/5 of the *Marine Vessel Rules*.
- ii) The CO₂ storage tank(s) are to be continuously monitored and protected against overfilling. Each tank is to be fitted with an independent high liquid level alarm operating independently of other liquid level indicators and giving an audible and visual warning at the remote-control position(s) and at the local control station when activated.

- iii) The high liquid level alarm is to operate at a level not higher than the maximum filling limit given by 6/4ii) and is to trigger automatic shutdown of the liquefied CO₂ supply line to the storage tank using the ESD valve(s) required by 6/5ii).
- iv) As per 6/3.1ii), the CO₂ storage system design, including the instrumentation, is to take into account the composition of the liquefied CO₂, water content and expected impurities, including the effect those impurities may have on the “triple point” temperature of the CO₂. The set pressure for the alarms and automatic actions described in this Section are to be set at least 0.05 MPa above the “triple point” for the specific composition of CO₂ being carried. The “triple point” for pure CO₂ occurs at 0.518 MPa absolute and -56.6°C.
- v) The CO₂ storage tank(s) are to be continuously monitored for low pressure and give an audible and visual warning at the remote-control position(s) and at the local control station when activated.
- vi) If the CO₂ storage tank(s) pressure continues to fall to within 0.05 MPa of the “triple point” for the specific composition of CO₂ being carried, the monitoring system is to automatically close all liquid and vapor lines using the ESD valves required by 6/5ii) and stop all associated compression, cooling or liquefaction equipment.
- vii) As applicable, hold spaces used for the location of CO₂ storage tank(s) are to be continuously monitored for CO₂ build up and oxygen concentration, as per Subsections 5/4v) and 5/4vi). Gas detection equipment is to meet the requirements of Subsection 7/5.

See also Subsection 6/8 for the requirements for monitoring, control and alarm systems.

4 Filling Limit and Pressure/Temperature Control

- i) The CO₂ storage tank(s) pressure and temperature are to be maintained at all times within the design range by either one, or a combination of, the following methods;
 - a) Reliquefaction of vapors
 - b) Liquid cooling
 - c) Pressure accumulation
- ii) The storage tanks are not to be filled to more than 98% full at the reference temperature, where the reference temperature is as defined in 5C-8-15/1.3 of the *Marine Vessel Rules*. The maximum operational loading limit for the CO₂ storage tanks is to be determined in accordance with 5C-8-15/5 of the *Marine Vessel Rules* and is to be included in the operation manuals.

Commentary:

The loading limit for Type C tanks will typically be considerably below the 98% filling limit depending on the set pressure of the pressure relief valves and whether any means of CO₂ temperature and pressure control are fitted. Consideration will be given for Type C tank loading limits to be calculated in accordance with 5C-8-15/5.2 of the *Marine Vessel Rules*.

End of Commentary

- iii) The methods of pressure and temperature control are to be sufficient to maintain the tank pressure below the set pressure of the tank pressure relief valves under all tank fill conditions and in consideration of the vessel operating profile. Calculations are to be submitted demonstrating this capability.
- iv) The design of any cooling or reliquefaction systems required for pressure and temperature control of the stored CO₂, are to be in accordance with 5/5.1ii).

5 Emergency Shutdown System

- i) All liquid and vapor line connections, including piping connections for gas freeing and unloading, on the CO₂ storage tank(s) are to be equipped with shut off valves located as close to the tank as

possible. These valves are to provide full closure and be capable of local manual operation. They may also be capable of remote operation.

- ii)* All liquid and vapor line connections on the CO₂ storage tank(s) are also to be equipped with remotely controlled emergency shutdown (ESD) valves located as close to the tank as possible. A single valve may be substituted to undertake this ESD valve function and the shut off valve requirements of 6/5i).
- iii)* The ESD valves are to be of the fail-closed type (close on loss of actuating power or pneumatic rotary actuator), be capable of manual closure and have positive indication of the valve position.
- iv)* The ESD valves are to close fully and smoothly within 30 seconds of operation and the design of the ESD system is to avoid the potential generation of surge pressures within the pipework. Information about the closing time of the valves and their operating characteristics is to be available on board, and the closing time is to be verifiable and repeatable.
- v)* All pipelines or components which may be isolated in a liquid full condition are to be protected with relief valves for thermal expansion and evaporation.
- vi)* The ESD system is to be capable of manual operation from the remote-control position(s) and at the local control station and is to automatically operate in accordance with the monitoring and safety shutdowns of Section 7, Table 3.
- vii)* As per 6/3.3iii), a means to isolate the pressure relief valves is to be provided.

6 Unloading Arrangements

- i)* Suitable unloading manifolds, pipework and control and monitoring systems are to be provided for unloading of liquefied CO₂. Arrangements are to be considered by the risk assessment required by Subsection 3/2.
- ii)* The unloading system is to be designed to prevent venting of CO₂ at all times during unloading operations.
- iii)* Control of unloading is to be from a safe location and, as a minimum, the CO₂ storage tank temperature and pressure, and unloading pump pressures are to be monitored from this location. It is also to be possible to activate the ESD system required by Subsection 6/5 from this location. Where operations are able to be monitored visually, or remotely by CCTV cameras, unloading control and monitoring may be from the remote-control position(s) or the local control station.
- iv)* Unloading manifolds are to be equipped with shut off valves. These valves are to provide full closure and be capable of local manual operation. They may also be capable of remote operation.
- v)* Local pressure gauges are to be located at the unloading manifold between the shut off valves and presentation flange.
- vi)* Liquefied CO₂ pumps are to be designed and tested in accordance with 5C-8-5/13.1.3 (IACS) of the *Marine Vessel Rules*.
- vii)* In the case of submerged pumps, arrangements are to be made to alarm at low-liquid level and automatically shut down the motors in the event of low-liquid level. The automatic shutdown may be accomplished by sensing low pump discharge pressure, low motor current, or low-liquid level. This shutdown is to give an audible and visual alarm at the local and, as applicable, remote control station(s).

7 Portable Tanks

- i)* Where portable tanks are used for CO₂ storage, the design is to be equivalent to that for permanent installed tanks as required by 6/3.1i). Refer to Subsection 2/4 for guidance on the acceptance of alternatives.
- ii)* The use of portable tanks or Multi Element Gas Containers (MEGC) certified to ISO or other recognized standards may be accepted subject to those tanks meeting, and being stowed, in

accordance with the requirements of the International Maritime Dangerous Goods (IMDG) Code for carriage of liquefied (UN 1058) or refrigerated (UN 2187) carbon dioxide, as applicable.

In those cases the filling limit as given by 6/4ii) is not applicable and tanks are not to be loaded beyond the maximum filling ratio applicable under the IMDG Code.

- iii)* Portable tanks are to be located in dedicated areas.
- iv)* Portable tanks are to be secured to the deck while connected to the vessel systems. The arrangement for supporting and fixing the tanks, including the underdeck supporting structure, is to be designed for the maximum expected static and dynamic inclinations, as well as the maximum expected values of acceleration, taking into account the vessel characteristics and the position of the tanks.
- v)* Consideration is to be given to the effect of the portable tanks on the vessel's stability.
- vi)* Connections to the vessel piping systems are to be made by means of approved flexible hoses or other suitable means designed to provide sufficient flexibility.
- vii)* Control and monitoring systems for portable tanks are to be integrated in the ship's OCCS control and monitoring system.

8 Monitoring, Alarm and Control Systems

Automatic control, monitoring, alarm, and safety functions are to be provided for the OCCS liquefied CO₂ storage tanks in accordance with Section 7.

The monitoring and safety shutdowns are to be in accordance with Section 7, Table 3.

Monitoring, Alarm and Control Systems

1 General

This Section provides the requirements for OCCS control, monitoring and safety systems that enhance the safety of operation and provide efficient operation of the installed systems. The requirements are to be applied in association with the applicable requirements of Part 4, Chapters 8 and 9 of the *Marine Vessel Rules* for electrical and automation systems respectively.

2 Plans and Data to be Submitted

Plans and specifications covering the control, monitoring and safety systems are, as applicable, to be submitted:

- i)* A general description of the operation of the system is to be provided. This is to include the system configuration, general arrangements for the vessel and the layout of the OCCS machinery with essential auxiliaries, specifications of main equipment with information of manufacturer's name, type, rating and number of the equipment.
- ii)* Details on control stations, local manual controls, instrumentation and communication systems.
- iii)* Descriptions and schematic diagrams of the control, monitoring and safety systems showing connections between all main components (units, modules) of the system, and including set points for abnormal conditions and associated shut off and shutdown systems.
- iv)* Failure Modes and Effects Analysis (FMEA) to determine possible failures and their effects in the safe operation of the OCCS system.

3 Control and Monitoring System

- i)* The control system for the OCCS system may be connected to an integrated control system or be a stand-alone system.
- ii)* An analysis is to be carried out for the system identifying component criticality. The overall system design is to be based on single-fault criteria. The system is to be designed such that a single fault of a component will not lead to a dangerous situation for human safety, the environment and/or the vessel.

The FMEA, or equivalent failure analysis methodology, demonstrating the design basis is to be submitted. See also 4-9-1/5.1.16 of the *Marine Vessel Rules*.

- iii)* The design of the control system is to be such as to ensure identification of faults in the equipment, as well as the process system. The control and monitoring systems are to comply with the requirements of 4-9-2/3.1, 4-9-2/7, and 4-9-2/9 of the *Marine Vessel Rules*, as applicable.
- iv)* Automatic control, monitoring, alarm, and safety functions are to be provided so that OCCS operations remain within preset parameters for all operating conditions. For vessels with **ACC** or

ACCU notations, the alarm and monitoring systems are to be integrated in the vessel's centralized monitoring systems that conform to the requirements for **ACC** or **ACCU** notations.

- v) Indications of parameters necessary for the safe and effective operation of the process, audible and visual alarms are to be provided at the local and manned control station(s), as per Section 7, Tables 1, 2 and 3. Audible and visual alarms are to be provided at the OCCS remote-control position(s) and at the local control station.

As applicable to the particular design, monitoring of CO₂ removal efficiency, CO₂ purity, water content or other required or proxy measurement is to be provided to enable operators to verify efficient operation of the OCCS system within the bounds of the equipment design.

Commentary:

Solvent condition monitoring, CO₂ flow rate, % CO₂ concentration before and after gas processing, impurities in the collected gas, acidity, and water content, washwater or bleed water discharge monitoring are examples of possible process monitoring parameters. The intent is to identify efficient operation and situations when the carbon capture process is operating outside of design parameters.

End of Commentary

- vi) Computer-based control systems are to comply with the applicable requirements of 4-9-3 of the *Marine Vessel Rules* as a Category II system based on 4-8-3/15 of the *Marine Vessel Rules*.
- vii) The power supply arrangements for the control and monitoring system are to meet the requirements of 4-9-2/5.3 of the *Marine Vessel Rules*.
- viii) The control and monitoring system is to be provided at a dedicated control station or the engine control room. Additionally, a local control and monitoring system and motor control panels are to be provided in the vicinity of OCCS system pumps, compressors, and fans to enable operation, maintenance and effective control in the event of an emergency or failure of any remote controls.
- ix) The control and monitoring system is to include compressor anti surge protection.
- x) All electronic control equipment is to be performance tested in the presence of the Surveyor or by a recognized testing laboratory, in accordance with the criteria of 4-9-9/Tables 1 and 2 of the *Marine Vessel Rules*.

4 Safety Shutdown System

A shutdown system is to be provided. The safety shutdown system is to be based on the following principles:

- i) Means are to be provided to indicate the parameters causing shutdown.
- ii) Upon activation of the safety shutdown system, alarms are to be given at the remote-control position(s) and at the local control station.
- iii) In the event where shutdown by the safety shutdown system is activated the restart is not to occur automatically, until the system has been manually reset.
- iv) Safety shutdowns are to be automatically activated for the conditions in Section 7, Tables 1, 2 and 3.

5 Gas Monitoring and Detection System

- i) Gas detection equipment is to be designed, installed, maintained, calibrated, and tested in accordance with a recognized standard.

The placement of the detectors is critical to the effectiveness of the gas detection system. The exact location of the gas detectors is to be determined taking into consideration the prevailing

airflow and sensitivity of the gas detectors. Arrangements will be subject to approval for each application based upon the gas dispersion analysis or the physical smoke test.

Refer to 5/4v), 5/4vi) and 6/3.4vii) for the requirements for CO₂ and O₂ monitoring of CO₂ machinery spaces and CO₂ tank hold spaces.

- ii) Gas detection is to be continuous without delay.
- iii) Gas detection systems are to be of the self-monitoring type.
- iv) In the event that a system fault is detected by the self-monitoring functions, the output of the detection system is to be automatically disconnected such that the detector fault will not cause false emergency shutdown.
- v) The gas detection equipment is to be designed so that it may be readily tested.
- vi) The gas detection system is always to be in operation, during normal operation and while purging prior to maintenance works.
- vii) At least two portable oxygen level gas detectors are to be provided that meet an acceptable recognized standard.

6 Exhaust Emission Monitoring Systems

- i) Where a vessel is fitted with an exhaust emission monitoring system for monitoring NO_x, SO_x, CO, HC, CO₂ or other gaseous or PM emissions, the **EEMS** notation is voluntary and will be assigned where the emission monitoring system meets the requirements of Section 6-3-5 of the *Marine Vessel Rules*.

Commentary:

The intent is that the ABS requirements supplement the statutory specification, calibration, testing, and survey requirements of the applicable IMO Regulations and Guidelines. At the time of publication of this document the only available IMO instruments are applicable to SCR and SO_x scrubber system monitoring. The statutory approval aspects under those IMO instruments, and others that may be developed specifically for CCS monitoring systems in the future, may be made by ABS as a separate parallel process in the capacity of a Recognized Organization for the vast majority of flag Administrations where the Administration has delegated these functions to a Recognized Organization, and subject to any additional requirements the Administration may impose.

End of Commentary

- ii) Emissions analyzers installed for the purposes of monitoring CO₂ concentrations or other process gases, or impurities are to be in accordance with the requirements of 6-3-5/9.7 of the *Marine Vessel Rules*.
- iii) Sample probes for gaseous emissions monitoring of CO₂ concentrations or other process gases or impurities are to be in accordance with the requirements of 6-3-5/9.3 of the *Marine Vessel Rules*.

TABLE 1
**Monitoring and Safety System Functions for Pre-Scrubbing/Quenching,
Absorber and Desorber Systems**

<i>Monitored Parameters</i> ⁽¹⁾	<i>Display</i>	<i>Alarm Activated</i>	<i>Automatic Shutdown</i>
Exhaust fan motors	Running	Stop ⁽²⁾	
Exhaust bypass or isolation valves, where provided	Position		
Control-actuating medium of the exhaust bypass or isolation valves	Running	Failed	
Exhaust gas temperature before EGC units	X	High	X (High-High)

<i>Monitored Parameters</i> ⁽¹⁾	<i>Display</i>	<i>Alarm Activated</i>	<i>Automatic Shutdown</i>
Exhaust gas temperature after EGC units	X	High	X (High-High)
Exhaust gas pressure before EGC units	X	High	X (High-High)
Differential pressure across EGC units	X	High	X (High-High) ⁽³⁾
Washwater and solvent/process system pumps	Running	Stop ⁽²⁾	
Washwater and solvent/process system valves	Position		
Control-actuating medium of the washwater and solvent/process system valves	Running	Failed	
Washwater or solvent/process system pump supply pressures	X	Low	X (Low-Low)
Washwater or solvent/process system temperature	X	Low/High	X (High-High)
Washwater or solvent/process media level in pre-scrubbing/quenching, absorber or desorber units	X	High	X (High-High) ⁽³⁾
Desorber, separator, dryer pressure	X	High	X (High-High)_
Process monitoring: Water content, purity, contaminants, CO ₂ removal ^(1,4)	X	Low/High	X (Low-Low) X (high-High)
Chemical/solvent storage tank temperature	X	Low/High	X (High-High)
Chemical/solvent storage tank level	X	Low/High	X (Low-Low)
Chemical/solvent storage tank drip trays	X	High	X (High-High) ⁽⁵⁾
Residue tank level	X	High	X (High-High)
Control and safety system power supply	Running	Failed	
Emergency shutdown	X	X	X

Notes:

- 1 As applicable in accordance with the specific OCCS system design and installation.
- 2 Failure of essential system motors driving pumps or fans is to activate the standby units, where fitted - see 4/3.4.3.
- 3 Automatic bypass of the OCCS EGC units as per 3/3.1vi).
- 4 As applicable to the particular design – see 7/3v).
- 5 Remote closure of the close coupled storage tank valves – see 4/4.3.1 of this document and 6-3-2/11.5 of the *Marine Vessel Rules*.

TABLE 2
Monitoring and Safety System Functions for Compression, Refrigeration and Liquefaction Systems

<i>Monitored Parameters</i> ⁽¹⁾	<i>Display</i>	<i>Alarm Activated</i>	<i>Automatic Shutdown</i>
Flow rate	X	Low	X (Low-Low)
Driving motors	Running	Stop ⁽²⁾	
Compressor lubricating oil pressure	X	Low	X (Low-Low)
Compressor lubricating oil temperature	X	High	X (High-High)

<i>Monitored Parameters</i> ⁽¹⁾	<i>Display</i>	<i>Alarm Activated</i>	<i>Automatic Shutdown</i>
Compressor suction line pressure	X	Low/High	X (Low-Low) X (High-High)
Compressor suction line temperature	X	High	X (High-High)
Compressor discharge line pressure	X	Low/High	X (Low-Low) X (High-High)
Compressor discharge line temperature	X	Low/High	X (High-High)
Heat exchanger inlet temperature	X	High	X (High-High)
Separator, dryer level	X	High	X (High-High)
Separator, dryer pressure	X	High	X (High-High)
Loss of ventilation in the CO ₂ machinery space ⁽³⁾	Running	Stop ⁽²⁾	
CO ₂ concentration in machinery spaces	X	High	X (High-High)
Oxygen concentration in machinery spaces	X	Low	X (Low-Low)
Refrigeration concentration, if considered toxic	X	High	X (High-High)
Control and safety system power supply	Running	Failed	
Emergency shutdown	X	X	X

Notes:

- 1** As applicable in accordance with the specific OCCS system design and installation.
- 2** Failure of essential system motors is to activate the standby units, where fitted - see 4/3.4.3.
- 3** See 5/4iv).

TABLE 3
Monitoring and Safety System Functions for Liquefied CO₂ Storage Tanks

<i>Monitored Parameters</i> ⁽¹⁾	<i>Display</i>	<i>Alarm Activated</i>	<i>Automatic Shutdown</i>
High or low liquid level ⁽²⁾	X	Low/High	X (Low-Low) X (High-High) ⁽³⁾
Driving motors	Running	Stop ⁽²⁾	
CO ₂ discharge temperature/pressure	X	Low/High	X (Low-Low) X (High-High)
High pressure in tank	X	High	X (High-High)
Low pressure in tank	X	Low	X (Low-Low) ⁽⁴⁾
High temperature in tank	X	High	
Low temperature in tank	X	Low	
CO ₂ concentration in hold space	X	High	X (High-High)
Oxygen concentration in hold space	X	Low	X (Low-Low)
Control and safety system power supply	Running	Failed	
Emergency shutdown	X	X	X

Notes:

- 1 As applicable in accordance with the specific OCCS system design and installation.
- 2 Overflow protection for tank to be by independent high liquid level alarm in accordance with 6/3.4ii) and low liquid level protection in accordance with 6/6vii).
- 3 Automatic activation of the supply line ESD valve as per 6/3.4iii).
- 4 Automatic activation of the liquid and vapor line ESD valves as per 6/3.4vi).

EGC-OCCS Ready Notation (1 December 2022)**1 General**

This section is applicable for the optional **EGC-OCCS Ready** notation. It is applied to vessels with design features that allow for future retrofitting of an OCCS system based on existing Class requirements at the time of engineering review. It is to be noted that any statutory or Flag administration requirements at the time of review or subsequent requirements at the time of installation are also to be complied with.

2 Scope and Application

The scope of this section is to define a three (3) level OCCS Ready program to provide details and preparations needed at each level, and to describe the notations ABS will offer subject to compliance at each level. These are briefly described below:

- **Ready 1C** – Concept Design review – indicates a high-level evaluation of the compliance of the basic suitability of a particular vessel design to fit an OCCS system.
- **Ready 2D** – Detail Design review – indicates a detailed evaluation of the compliance of the suitability of a particular vessel design to fit an OCCS System.

The “**EGC-OCCS Ready 2D**” notations associated with the subgroups detailed in Subsection 8/4 are to be assigned the notation **EGC-OCCS Ready 2D (xxx)**. Example notations with descriptive letters (see 8/4 Table 1 for descriptive letter listing) are shown below:

- i)* Hull structural arrangement and reinforcement- **EGC-OCCS Ready 2D (HS)**
- ii)* OCCS system configuration and vessel integration- **EGC-OCCS Ready 2D (SC)**
- **Ready 3** – Installation Ready review – extends the Class approval of the drawings to the installation of parts of the system or complete system onboard the vessel including Survey in accordance with applicable requirements of this document and related *Marine Vessel Rules*.

The “**EGC-OCCS Ready 3**” notations associated with the subgroups detailed in Subsection 8/4 are to be assigned the notation **EGC-OCCS Ready 3 (xxx)**. Example notations with descriptive letters (see 8/4 Table 1 for descriptive letter listing) are shown below:

- i)* CO₂ Compression, Refrigeration and Liquefaction Systems - **EGC-OCCS Ready 3 (CRL)**
- ii)* Pre-Scrubbing/Quenching system, Absorber and Desorber Systems- **EGC-OCCS Ready 3 (CC)**

Based on the above determination and successfully completing the review/ survey process, a notation with appropriate descriptive letters will be assigned to a vessel e.g., “**EGC-OCCS Ready 1C**” or “**EGC-OCCS Ready 2D (CRL)**” or “**EGC-OCCS Ready 3 (CC)**”.

It should be noted that a vessel may be assigned a combination of notations such as **EGC-OCCS Ready 2D (CRL)** and **EGC-OCCS Ready 3 (HS)** whereby:

- i) **Ready 3 (HS)** would cover the “Hull Structural Arrangement and Reinforcement” installation; which includes compliance with the detailed design review **Ready 2D (HS)**; and
- ii) **Ready 2D (CRL)** would cover the detailed design review of "CO₂ compression, Refrigeration and Liquefaction System".

3 Ready 1C- Concept Design Review

The Concept Design Review is a high-level evaluation of the suitability of a vessel design to incorporate an OCCS system. The high-level evaluation considers if the geometry and structural arrangements of the vessel can physically encompass the necessary equipment, in compliance with the requirements in this document at the time of the review. Upon satisfactory completion of this review level, ABS will assign a class notation, e.g., **EGC-OCCS Ready 1C** to indicate the Concept Design Level. The concept design is to consider accommodating a specific type of system/systems, so that the same type of system can be installed in the future.

3.1 Plans and Data to be Submitted

The following plans and documentation shall be submitted for review:

3.1.1 Vessel Specific Drawings

- Ship general arrangement indicating the location of OCCS
- Preliminary study on Load Line and Stability in respect to the effect of the OCCS system installations and arrangement
- Machinery space arrangement drawing indicating the layout and location of the OCCS components onboard

3.1.2 OCCS Configuration Drawings

- Physical size of the system and the available space onboard
- General description and schematic diagram of OCCS components
- Arrangement and capacity of tanks for storage, chemicals, process wash water, exhaust gas cleaning residues, Liquid CO₂, Final by-product (e.g., CaCO₃) etc.

3.1.3 Pre-Scrubbing/Quenching, Absorber and Desorber Systems

- Exhaust gas system arrangement indicating the water wash system, absorber and desorber units, if applicable

3.1.4 CO₂ Compression, Refrigeration and Liquefaction Systems

- Details of CO₂ liquefaction system and/or other chemical processing systems, if applicable

3.1.5 Chemical Treatment System

- Details of chemical treatment system arrangement, if applicable

3.1.6 Statutory Requirements

The design shall comply with statutory or other requirements, if any, of the competent authority as applicable, at the time of installation.

4 Ready 2D- Detail Design Review

This Level is additional to **Ready 1C**, and it is categorized in separate design groups identifying the different components of the complete design.

The drawings and supporting documentation are to be reviewed for compliance with this document and the base Rules applied for Classification of the vessel. The detailed design is to evaluate specific systems, components, structural elements or the complete system design.

Upon satisfactory completion of this review, ABS will assign a class notation, e.g. **EGC-OCCS Ready 2D** to indicate the detail design stage review including descriptive letters for the component(s) or system(s) for which the design was reviewed. The detailed drawings could then be used as part of the retrofit project pending Class and flag state agreement at the time of installation.

The subgroups are as given in the following table:

TABLE 1
EGC-OCCS Ready Notation Subgroups and Descriptive Letters

<i>System Components or Systems</i>	<i>Descriptive Letters</i>
Hull Structural Arrangement and Reinforcement	HS
OCCS System Configuration and Vessel Integration	SC
Pre-Scrubbing/Quenching system, Absorber and Desorber Systems	CC
CO ₂ Compression, Refrigeration and Liquefaction Systems	CRL
Chemical Treatment System	C
Liquid CO ₂ and/or final by-product storage and discharging system	LCS
Exhaust Gas System	EG
Monitoring, Alarm and Control System	MACS

The above descriptive letters will be included in the vessel record when the drawings and supporting documents of the OCCS equipment or system as indicated in the above subgroups has been reviewed and approved by ABS per the applicable ABS Rule/Guide requirements.

4.1 Plans and Data to be Submitted

The plans and documents to be submitted for each group of **Ready 2D** are listed below.

Commentary:

The level of submitted documentation may be reduced by prior agreement where, for example, the design is not fully developed, and a simplified drawing package is prepared for owners to specify instructions to the builder for technical or commercial purposes.

End of Commentary

4.1.1 Hull Structural Arrangement and Reinforcement

- Hull structural arrangement where the OCCS systems are installed
- Each OCCS equipment, component foundation and attachments to the vessel's structure
- Hull reinforcement for accommodating the OCCS system equipment

4.1.2 OCCS System Configuration and Vessel Integration (see Section 3/3.1 of the OCCS Requirements)

- Specifications for OCCS system and Fuel Oil Combustion Units (FOCU)
- Compatibility analysis of the OCCS system with FOCU (see 3/3.1 of the OCCS Requirements)
- General arrangement of the OCCS system installation and auxiliary equipment

- Schematic diagram for every system of the OCCS
- Electrical load analysis
- Schematic diagram and description of control and monitoring systems
- Emergency shutdown arrangement
- Description of the redundancy configuration
- Documentation detailing the effect on Load Line and Stability of the OCCS system, in accordance with see 3/3.6 of the OCCS Requirements
- Risk Assessment in accordance with Section 3/2

4.1.3 Pre-Scrubbing/Quenching, Absorber and Desorber Systems (Requirements for OCCS)

Refer to 3/4.1, 3/4.2, 4/3 and 4/4.

- Schematic drawings, descriptions of every component of each system
- Detail piping design with diagram and associated components of each system
- Wash water piping system with diagram and associated components
- Arrangement and capacity of tanks for storage and wash water treatment system
- Pre-scrubbing wash water supply and overboard discharge arrangement
- Residue system including piping diagram and associated components
- Arrangement and capacity of residue tank
- Sea chest arrangement and capacity

4.1.4 CO₂ Compression, Refrigeration and Liquefaction Systems (Section 5 of the Requirements for OCCS)

Refer to Section 5.

- Schematic diagram and description of the CO₂ system design and capacity
- Location of the CO₂ machinery space
- Detail of the system equipment, piping

4.1.5 Chemical Treatment System, if Applicable

Refer to 4/4.

- Chemical treatment piping system including piping diagram and associated components
- Arrangement and capacity of the NaOH/ Ammonia/ CaO storage tank and overflow tank
- General arrangement of NaOH/ Ammonia/ CaO bunker station system

4.1.6 Liquid CO₂ and/or Final By-product Storage and Discharging System (Section 6 of the Requirements for OCCS)

Refer to Section 6.

- General arrangement and detail design of the CO₂ storage tanks
- Vent mast and venting arrangements for the CO₂ storage system
- Diagrams with details of storage where final byproduct is not liquid CO₂
- Details of the unloading arrangements

4.1.7 Exhaust Gas System

Refer to 4/4.1.

- Exhaust gas piping system including piping diagram and associated components
- Exhaust gas isolation and bypass valves arrangement

4.1.8 Monitoring, Alarm and Control Systems (Requirements for OCCS)

Refer to 4/5 and 7/Tables 1 to 3.

- Details of the automatic control, monitoring, alarm and safety functions are to be provided for each system

5 Ready 3- Installation Ready Review

This level of the **EGC-OCCS Ready** incorporates both the Class Approval of the detailed drawings and the installation of relevant structural members, piping, flanges, valves, electrical wirings of every equipment/ component of the OCCS system so that during retrofitting equipment/ component can be installed with minimum to no modifications or changes.

Ready 3 requires approval of the complete list of drawings of each section of the OCCS system in compliance with this document. All piping and electrical connections including major structural works are to be completed according to the approved drawings. Upon completion of all works to the satisfaction of the attending Surveyor, the vessel will be eligible for the optional notation **EGC-OCCS Ready 3**.

The design groups and descriptive letters for **Ready 3** are the same as **Ready 2D** in 8/4 above. The descriptive letters will be included in the vessel record when the item of equipment or system of the OCCS design groups indicated in 8/4 above has been design approved as per the applicable ABS requirements and installed/surveyed onboard to the satisfaction of the attending Surveyor.

6 Survey During Construction

ABS Surveyor attendance during manufacturing at the factory and/or installation on board is required for verification of compliance with the applicable *Marine Vessel Rules* and the requirements in this document for assignment of the **EGC-OCCS Ready 3** notation. A survey report will be issued to document that the OCCS System/Equipment has been design reviewed and installed as indicated in 8/5 above.

SECTION 9

Surveys and Maintenance of Class

1 General

This Section pertains to survey during construction and periodical surveys after construction for the equipment described in Sections 1 to 7.

1.1 Definitions

For definitions related to the surveys of equipment covered by this document, see Subsection 2/2 of this document and 7-1-1/3 of the *ABS Rules for Survey After Construction (Part 7)*.

1.2 Modifications

When it is intended to carry out any modifications to the OCCS system, associated components, or monitoring equipment, which may affect classification, including substitutions of material differing from that originally installed, the details of such modifications are to be submitted for review. If ABS determines that the modification will affect classification, the affected system or component to be modified will be subject to the review, testing, and survey requirements in accordance with this document.

2 Survey During Construction

2.1 General

This subsection pertains to surveys during fabrication at the manufacturer's facility and installation and testing of OCCS systems onboard. For surveys at the manufacturer's facility, the scope of the survey will be confined to only those items that are supplied by the manufacturer.

2.2 Surveys at Manufacturer's Facility

Construction and testing of OCCS units, equipment, systems, components, and associated piping is to be in accordance with Section 9, Table 1.

Certification of the complete OCCS system cannot be accepted based solely on the ABS Type Approval Program, and therefore ABS Surveyor's attendance is required during fabrication for unit certification. However, component parts of the unit can be certified in accordance with ABS Product Quality Assurance (PQA) Certification system outlined in Appendix 1-1-A3 of the *ABS Rules for Conditions of Classification (Part 1)*.

When Surveyor's attendance at the shop of the manufacturer and at the assembly site is required by the applicable Rules, the manufactured/assembled system components will be verified to be satisfactorily in compliance with the aforementioned Rules. Surveyor's attendance is required typically for the following purposes:

- i) To confirm that the facility to manufacture, fabricate or repair OCCS systems or their components does have and maintain a quality-control program effectively covering design, procurement,

manufacturing and testing, as applicable, and meeting the requirements of a recognized standard applicable to their product.

- ii) To qualify or verify welder's qualifications, welding procedure specifications and corresponding weld procedure qualification records to the extent deemed necessary by the attending Surveyor.
- iii) To verify material certificates/documentations, particularly for materials of piping, main pressure retaining parts of valves, including safety valves that have flanged or threaded ends or other specialty fittings. Material testing is to be witnessed where required by the *Marine Vessel Rules*.

Materials for liquefied gases are to comply and be tested and certified in accordance with the applicable requirements of 5C-8-6 of the *Marine Vessel Rules*.

- iv) To survey final weldments. Construction relating to CO₂ tank and piping welding, and testing, is to be in accordance with 5C-8-4/20, 5C-8-6/5 and 5C-8-6/6 of the *Marine Vessel Rules*.
- v) To witness, as far as deemed necessary, weld nondestructive examination tests and to review records of nondestructive examinations.
- vi) To witness pressure and/or proof-load testing of equipment components and as a unit, as applicable and as called for in the fabrication process.
- vii) To witness testing of subassemblies and completed units as called for in the fabrication process.
- viii) To verify all certified safe systems, motor controllers, consoles and instrumentation and control panels are in compliance with approved drawings.
- ix) To carry out other inspections and to witness the final Factory Acceptance Test (FAT) as agreed upon during the prefabrication meeting.

2.3 Surveys During Installation

The following surveys are to be carried out to the satisfaction of the attending Surveyor on the OCCS units and associated systems during installation and testing:

- i) Inspection and verification that the foundations and attachments of the principal components of the OCCS units and associated systems are in accordance with the approved plans and particulars.
- ii) Piping systems are to be visually examined and pressure-tested, as required by the *Marine Vessel Rules*. Pressure tests conducted on Class I piping (see 4-6-1/5 TABLE 1 of the *Marine Vessel Rules*) systems are to preferably be recorded on test charts for the duration of their tests.
- iii) Electrical wiring and connections are to be in accordance with Part 4, Chapter 8 of the *Marine Vessel Rules* and checked for continuity and proper workmanship.
- iv) Instrumentation is to be tested to confirm proper operation as per its predetermined set points.
- v) Pressure relief and safety valves are to be tested.
- vi) Control system and shutdowns are to be tested for proper operation. Functional testing of alarms for monitoring and safety functions with reference to Section 7, Tables 1, 2, and 3 and as applicable. The operational testing is to be carried out to the Surveyor's satisfaction to demonstrate the level of redundancy established by the FMEAs.
- vii) The OCCS units are to be checked for proper operation in accordance with the submitted installation test procedures.
- viii) Availability of operation manuals, Trial Test Procedures/Results of Trials and FMEA onboard is to be verified.

2.4 Surveys During Trials

During the initial commissioning trials, the OCCS systems are to be confirmed for satisfactory operation, including associated controls, alarms, and shutdowns. The tests are to be conducted in accordance with the submitted testing procedure during sea trials.

3 Survey After Construction

3.1 Annual Survey

An Annual Survey of a vessel fitted with an OCCS system is to be carried out within three (3) months before or after each annual anniversary date of the crediting of the previous Special Periodical Survey or original construction date. For vessels on Continuous Survey, all Continuous Survey requirements for those parts (items) due are generally to be completed each year. The Annual Survey will not be credited and the Certificate of Classification will not be endorsed unless Continuous Survey items that are due or overdue at the time of the Annual Survey are either completed or granted an extension.

For annual survey, the survey is to include the applicable requirements of 7-9-29/1.1, 7-3-2/1.13.1 through 1.13.4, 7-3-2/1.13.8 and 7-6-2/1.5.3 of the *Marine Vessel Rules* for exhaust emission and CO₂ stripping equipment, liquefied CO₂ containment and associated systems, together with reliquefaction equipment, as applicable to the particular OCCS system design.

Additionally, the annual survey is to include:

- i) The OCCS units and systems are to be checked for proper operation in accordance with the submitted test procedures and operation manuals
- ii) Functional testing of alarms for monitoring and safety functions with reference to Section 7, Tables 1, 2, and 3 and applicable FMEAs.
- iii) Testing of portable oxygen level detectors.
- iv) Examination of all other personnel safety and PPE equipment specific to the OCCS systems.

3.2 Intermediate Survey

Intermediate Surveys of OCCS equipment, associated systems, and monitoring equipment is to be carried out either at or between the second and third Annual Surveys after Special Periodical Survey No. 1 and subsequent Special Periodical Surveys.

Those items which are additional to the requirements of the Annual Surveys may be surveyed either at or between the second and third Annual Surveys.

In addition to subsection 3.1 above, for intermediate surveys, the survey is to include testing as provided by 7-6-2/3.11.2(a) of the *Marine Vessel Rules*.

3.3 Special Periodical Survey

A Special Periodical Survey of OCCS equipment, associated systems, and monitoring equipment is to be completed within five years after the date of construction or after the crediting date of the previous Special Periodical Survey. The fifth Annual Survey must be credited as a requirement of the Special Periodical Survey. The interval between Special Periodical Surveys may be reduced by the Committee.

The Special Periodical Survey may be commenced at the fourth Annual Survey and be continued with completion by the fifth anniversary date. Where the Special Periodical Survey is commenced prior to the fourth Annual Survey, the entire survey is to be completed within fifteen (15) months if such work is to be credited to the Special Periodical Survey.

A Special Periodical Survey will be credited as of the completion date of the survey but not later than five years from date of construction or from the date recorded for the previous Special Periodical Survey. If the special Periodical Survey is completed within three (3) months prior to the due date, the Special Periodical Survey will be credited to agree with the effective due date. Special consideration may be given to Special Periodical Survey requirements in unusual cases. Consideration may be given for extensions of Rule required Special Periodical Surveys under exceptional circumstances.

In addition to subsection 3.2 above, for special surveys, the survey is to include testing of the applicable equipment and systems given by 7-9-29/1.3, 7-3-2/5.11.1 and 7-6-2/3.3.3 of the *Marine Vessel Rules*.

The main components and equipment of the OCCS installation are to be examined to the satisfaction of the attending Surveyor at the Special Periodical Survey including, but not limited to, and as applicable to the particular OCCS installation:

- i) Pre-scrubbing/quenching, absorber and desorber units including associated pumps.
- ii) Exhaust gas piping, extractive fans and valves including bypass and isolation valves.
- iii) Chemical and process media treatment systems including associated pumps.
- iv) The CO₂ machinery space arrangements including ventilation systems.
- v) Compressors, dryers, separators, heat exchangers, pumps and equipment for compression and liquefaction of the collected CO₂ and temperature/pressure control.
- vi) The CO₂ storage tanks and associated valves, pumps, piping and unloading arrangements.
- vii) Electrical equipment.
- viii) Instrumentation, control, monitoring, gas detection and safety systems including verification of the calibration.
- ix) Personal Protective Equipment.

TABLE 1
Certification of Onboard Carbon Capture Systems at the Manufacturer's Facility

This Table is provided for guidance only and annotated to agree with the *Marine Vessel Rules*. The list is not exhaustive; where additional equipment not listed is fitted onboard, same will be subject to special consideration for compliance with the *Marine Vessel Rules*. This list is not to be considered as substitutive or integrative of the content of the *Marine Vessel Rules* and/or other applicable Regulations. In case of conflict between the content of this list and the applicable *Marine Vessel Rules* and other applicable regulations, the latter are to be considered applicable.

<i>Code</i>	<i>Explanation</i>			
DR	<i>Design Review</i> – Design review required.			
MS	<i>Manufacture Survey</i> – Product is to be surveyed during fabrication stages by the Surveyor.			
FS	<i>Final Survey</i> - Finished product is to be subject to final hydrostatic or alternative (e.g., compressed air), nondestructive, operational testing, or any other required tests, and witnessed by the Surveyor at manufacturer's facility.			

<i>Equipment</i> ⁽¹⁾	<i>DR</i>	<i>MS</i>	<i>FS</i>	<i>Reference</i>
Pre-scrubbing/quenching, absorber and desorber units	X	X	X	3/3.1viii), 4/1, 4/4.1.1,
Exhaust bypass or isolation valves	X			4/3.1, 4/4.1.2
Fan, pump and compressor motors ⁽²⁾	X		X	4/3.1, 4/3.4.1, 5/5.3
Heat exchangers/process pressure vessels/separators/dryers ⁽³⁾	X		X	4/3.2, 4/3.3, 5/5.4
Washwater, solvent and essential OCCS system pumps	X		X	4/3.1i)
Washwater, solvent, residue and associated piping systems	X		X ⁽⁴⁾	4/4.2, 4/4.3, 4/4.4
Compressors	X		X	5/5.3

<i>Equipment ⁽¹⁾</i>	<i>DR</i>	<i>MS</i>	<i>FS</i>	<i>Reference</i>
Reliquefaction and refrigeration systems	X		X	5/5.1, 6/4
Gas stream and liquefied CO ₂ piping systems	X	X ⁽⁵⁾	X	5/6
Liquefied CO ₂ tanks	X	X ⁽⁵⁾	X	6/3.1, 6/3.2
Liquefied CO ₂ tank pressure relief valves, ESD valves and associated piping	X	X ⁽⁵⁾	X	6/3.3
Liquefied CO ₂ pumps	X		X	5/5.5, 6/6vi)
Liquefied CO ₂ unloading manifold and associated piping	X	X ⁽⁵⁾	X	6/6
Gas detection and monitoring system	X		X	7/5
Control, monitoring and safety system	X		X	4/5, 5/7, 6/3.4, 6/5, 6/8, 7/3, 7/4, 7/6

Notes:

- 1** As applicable in accordance with the specific OCCS system design and installation.
- 2** Applicable for motors over 100 kW (135 hp) only. For motors less than 100 kW (135 hp), certification by ABS not required, acceptance based on manufacturer's documentation and guarantee - see 4/3.4.1.
- 3** As applicable, in accordance with 4/3.2, 4/3.3 and 5/5.4 of this document – see also 4-4-1/Table 1 of the *Marine Vessel Rules*.
- 4** Dependent on Class of piping system – see 4-6-1/5 TABLE 1 of the *Marine Vessel Rules*.
- 5** Material testing as required by 5C-8-6 of the *Marine Vessel Rules* – see 6/3.2 and 9/2.2iii) of this document.