財團法人驗船中心
CR CLASSIFICATION SOCIETY

GUIDELINES FOR ONBOARD CARBON CAPTURE AND STORAGE

CR CLASSIFICATION SOCIETY

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GUIDELINES FOR ONBOARD CARBON CAPTURE AND STORAGE

CONTENTS

Abbreviations

CCTV	Closed-Circuit Television
EEMS	Exhaust Emissions Monitoring System
EGC	Exhaust Gas Cleaning
ESD	Emergency Shutdown
FMEA	Failure Modes and Effects Analysis
IMDG	International Maritime Dangerous Goods
IMO	International Maritime Organization
ISO	International Organization for Standardization
LSA	Life Saving Appliances
MARPOL	The IMO International Convention for the Prevention of Pollution from Ships, 1973, as modified by the protocol of 1978.
MEGC	Multi Element Gas Containers
OCCS	Onboard Carbon Capture and Storage
PPE	Personal Protective Equipment
SDS	Safety Data Sheet

Chapter 1 General

1.1 Introduction

1.1.1 The provisions of the Guidelines for Onboard Carbon Capture and Storage (hereinafter referred to as the Guidelines) are applicable to Onboard Carbon Capture and Storage (OCCS) systems installed to reduce CO_2 emissions onboard the ships. The Guidelines provide the classification requirements for the design, onboard installation and arrangement, control and monitoring, survey and testing, etc. of OCCS.

1.1.2 The conventional ship systems and/or equipment shared with OCCS are to comply with relevant requirements of international conventions, Codes, and the Rules for the Construction and Classification of Steel Ships (hereinafter referred to as the Rules for Steel Ships) published by CR Classification Society (hereinafter referred to as the Society).

1.1.3 The Guidelines apply to OCCS using organic amine as decarbonization agent. Special consideration is to be given for the OCCS using other types of decarbonization agent or methods. In addition to the provisions of the Guidelines, OCCS is also to comply with the relevant requirements of the Rules for Steel Ships or other applicable Guidelines of the Society and the requirements of the competent authorities.

1.1.4 The Guidelines are to be applied to both new construction and existing ships and offshore units, regardless of size, including those of less than 500 gross tonnage.

1.2 General

1.2.1 The goals and principles of the Guidelines 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 ship, crew, and environment.

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

(a) 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 and temperatures. The engine maker’s pre-approval is required.

(b) OCCS systems are to be designed to enable continued operation of the fuel oil combustion unit(s) during times when the Exhaust Gas Cleaning (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).

(c) Materials of construction and workmanship are to be in accordance with the requirements of Part XI and Part XII of the Rules for Steel Ships and Chapter 6 of the Guidelines for Ships Carrying Liquefied Gases in Bulk (hereinafter referred to as the LGC Guidelines), 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.

(d) 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 Personal Protective Equipment (PPE), together with emergency treatment facilities, appropriate to the hazards concerned, are to be provided.

(e) Means are to be provided to suitably mitigate the risk to the fuel oil combustion unit(s) or ship from internal flooding associated with water scrubbing systems.

(f) 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.

(g) OCCS systems are to be designed and installed to avoid the presence of dangerous or detrimental vibration that reduces the safety and reliability of the installed equipment or pose a hazard to the ship or crew.

(h) OCCS systems are to be designed to be fully functional for the expected ship motions, including all degrees of list and trim per 1.6.1 of Part IV of the Rules for Steel Ships.

(i) 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 ship's crew or passengers.

(j) 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.

(k) Means are to be provided to process and store the captured CO_2, and for the equipment, piping, and containment of the CO_2 to be appropriately arranged to mitigate the risk to the crew, ship, or environment from chemical, gaseous, liquid or solid leaks or venting that may occur during operation of the OCCS systems.

(l) 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.

(m) 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.

(n) 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.

(o) Automation, instrumentation, monitoring, and control systems are to be provided to facilitate automated operation and monitoring of OCCS systems.

(p) 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.

(q) Fire detection, protection and extinguishing arrangements are to be provided to protect the ship and crew from possible fire hazards associated with the operation of OCCS systems and their associated systems.

(r) OCCS systems are to be arranged for easy inspection and maintenance and where applicable the ability to replace internal components is to be provided.

(s) Operating and maintenance instruction manuals are to be provided for all OCCS systems and associated equipment and systems to facilitate handling, operation, maintenance, and repair.

1.3 Class Notations

1.3.1 Where an OCCS system is fitted onboard, the **OCCS** notation is mandatory and will be assigned where the OCCS system is designed, constructed, and tested in accordance with the requirements of Chapters 1 to 7 of the Guidelines.

1.3.2 OCCS ready ships are to be assigned with optional class notations **OCCS Ready-I**, **OCCS Ready-II** or **OCCS Ready-III(X)** after confirming that the ships are in compliance with the relevant requirements as described below:

(a) **OCCS Ready-I**: concept design and approval of principle drawings are carried out for OCCS ready ship to ensure that the ship is in compliance with the basic requirements for future installation of OCCS, and that no equipment or systems related to OCCS systems have actually been installed on board;

(b) **OCCS Ready-II**: detailed design and approval of detailed drawings are carried out for OCCS ready ship to ensure that the OCCS ready ship is in compliance with the relevant requirements of the Guidelines, and that no equipment or systems related to OCCS systems have actually been installed on board;

(c) **OCCS Ready-III(X)**: extends the approval of the drawings to the installation of parts of the system or complete system onboard the ship including survey in accordance with applicable requirements of the Guidelines and the Rules for Steel Ships. The symbol **X** represents one or more suffixes of class notation, with the following specific meanings:

(i) The hull structures and related supporting structures have been strengthened, represented by the capital letter **S**;

(ii) The pre-scrubbing/quenching system, absorber and desorber systems have been installed, represented by the capital letter **E**;

(iii) The CO_2 compression, refrigeration and liquefaction systems have been installed, represented by the capital letter **L**;

(iv) The CO_2 storage tanks have been installed, represented by the capital letter **T**.

(d) Plans and data

(i) In addition to submitting the plans and data in accordance with the relevant requirements of the Rules for Steel Ships and the Guidelines, ships applying for the class notation **OCCS Ready-I** are also to provide:

(1) The following plans and data are to be submitted for approval, as a minimum:

a) General arrangement, including the reserved layout of OCCS;

b) Power load calculation sheet.

(2) The following plans and data are to be submitted for information, as a minimum:

a) OCCS Ready and layout instructions;

b) OCCS steam consumption calculation sheet (if applicable);

c) Longitudinal strength calculation sheet (taking into account the impacts of OCCS on ship weight distribution).

(ii) Ships applying for class notations **OCCS Ready-II** or **OCCS Ready-III(X)** are to submit the plans and data in accordance with the requirements in the Guidelines.

(e) Surveys

(i) Ships applying for class notation **OCCS Ready-III(X)** are to be surveyed in accordance with the applicable requirements of Chapter 7 in the Guidelines.

(ii) The equipment related to OCCS installed at the ready stage is to be surveyed in accordance with the relevant requirements of the Rules for Steel Ships and the Guidelines.

1.4 Risk Assessment

1.4.1 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.

1.4.2 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 the Society.

1.4.3 The risk assessment is to be developed and submitted to the Society 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 ship. Any modification is to be documented and submitted to the Society.

1.4.4 In addition to the general risks detailed in 2.2.2, 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 2.4.1.

(b) Location and impacts of the OCCS desorber or stripping units. See 2.4.2.

(c) Location and impacts of the OCCS chemicals, solvents, or consumables. See 2.4.3 and 3.4.3(a).

(d) Location and impacts of the CO_2 processing equipment. See 2.4.5.

(e) Location and impacts of the CO_2 storage tanks or carbon compound disposal and/or storage tanks and unloading arrangements. See 2.4.6 and 5.6.1.

(f) Required type and number of personal safety and PPE, together with number and location of eyewash and decontamination showers, as applicable to the specific OCCS system and installation arrangements. See 2.5.

1.5 Definitions and Abbreviations

1.5.1 Absorber

A component of the OCCS system designed to absorb CO_2 into an absorber media such as an amine solvent, ammonia water and NaOH water.

1.5.2 Amine

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

Note:
Amines are used to remove CO_2 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.

1.5.3 Ammonia water

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

1.5.4 CO_2 machinery space

Spaces where the CO_2 compressors, cooling, drying and liquefaction plant and pumps are located.

1.5.5 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.

1.5.6 Desorber

Also known as a stripping unit; a component of the OCCS system designed to remove, or desorb, the CO_2 from the absorber media.

1.5.7 Exhaust Gas Cleaning (EGC)

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.

1.5.8 Fuel oil combustion unit

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

1.5.9 NaOH water

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

1.5.10 Onboard Carbon Capture and Storage (OCCS) system

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 CO_2 to absorber media), a desorber or stripping unit (which removes CO_2 from absorber media), followed by further CO_2 processing and cleaning steps, including compression and cooling to liquefy the CO_2, which is then transferred to the dedicated CO_2 storage and temperature/pressure management system.

1.5.11 OCCS residue

OCCS residue means the substances separated from the absorbent filters or other residues generated by OCCS.

1.5.12 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.

1.5.13 Pre-scrubbing/quenching

A unit that cleans and cools the exhaust gas prior to the CO_2 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.

1.5.14 Safety Data Sheet (SDS)

Previously referred to as material safety data sheet or product safety data sheet.

1.5.15 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.

1.5.16 Scrubber

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

1.5.17 Triple point

The transition point on a phase diagram where all 3 phases of a gas can exist in equilibrium. For CO_2 the triple point is 0.518 MPa absolute at -56.6°C and at atmospheric pressure solid CO_2, known as dry ice, sublimates from solid to gas at -78.5°C.

1.6 Operating and Maintenance Instruction Manuals

1.6.1 Detailed operating and maintenance instruction manuals are to be provided onboard, covering routine operations between dry-docking intervals, safety, Emergency Shutdown (ESD), maintenance and training requirements and occupational health hazards relevant to the particular OCCS and associated systems.

1.6.2 The manuals are to include, but are not limited to, the following:

(a) Regular testing;

(b) Calibration and maintenance procedures and schedules for the control and monitoring systems;

(c) Alarm settings and safety shutdown systems;

(d) Integrity of backup systems together with identification of the relevant responsible parties;

(e) Special instructions on refueling, storage, and use of hazardous and non-hazardous chemicals intended for system operation;

(f) Emergency handling procedures, such as operating procedures for ESD, exhaust bypass and isolation, absorbent leakage, CO_2 leakage, emergency cleaning, ventilation and protection, as well as the arrangement for responsible personnel;

(g) Training and routine maintenance records.

1.6.3 The operating and maintenance instruction manuals are to be submitted to the Society for reference purposes.

1.7 Alternatives

1.7.1 Equipment, components, and systems for which there are specific requirements in the Guidelines, or its associated references, may incorporate alternative arrangements or comply with the requirements of alternative recognized standards in lieu of the requirements in the Guidelines.

However, this is subject to such alternative arrangements or standards being determined by the Society as being not less effective than the overall safety and strength requirements of the Guidelines or associated references. Where applicable, requirements may be imposed by the Society in addition to those contained in the alternative arrangements or standards so that the intent of the Guidelines is met.

1.7.2 In all cases, the equipment, component or system is subject to design review, survey during construction, tests and trials, as applicable, by the Society for purposes of verification of its compliance with the alternative arrangements or standards. The verification process is to be equivalent to that outlined in the Guidelines.

Chapter 2 Arrangements

2.1 Plans and Data

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

(a) Risk assessment (See 1.4).

(b) General arrangement of the OCCS components indicating the location and layout onboard.

(c) Details of OCCS system:

(i) EGC pre-scrubbing/quenching and absorber systems.

(ii) CO_2 separation arrangements including desorbers or stripping systems and associated auxiliary equipment.

(iii) Compression, refrigeration, and liquefaction systems.

(d) CO_2 or carbon compound disposal and/or storage arrangements.

(e) Vent mast and venting arrangements for the CO_2 storage system.

(f) Control and monitoring, safety shutdown, gas detection and emissions monitoring systems.

(g) Operating and maintenance instruction manuals (to be submitted for reference purposes).

(h) For existing ships, documentation related to weights and centers calculations due to OCCS retrofit is to be submitted.

2.2 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.

2.3 System Configuration

2.3.1 EGC compatibility and exhaust bypass

(a) 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.

(b) 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 ship’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.

(c) 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 2.3.1(e).

Note:

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

(d) 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.

(e) 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 is out of service, the capacity of the remaining ventilation fan(s) is not less than 100% of the total required.

(f) An EGC unit fitted to a ship 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.

(g) 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.

(h) 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 the Society for dry running of the EGC unit.

(i) 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.

2.3.2 Redundancy

(a) 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 2.3.1(e), 2.3.3, 3.3.1(b) and 3.3.4(c).

(b) 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 the Society 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 ship's propulsion and maneuvering capability.

(c) The carriage of sufficient spare parts onboard is an example of ship specific arrangements that may be considered by the Society as meeting this objective and is to be justified with reference to the Failure Modes and Effects Analysis (FMEA) required by 6.3.2.

2.3.3 Essential services

For the purposes of design, construction, testing, and survey, OCCS units and associated components and systems are considered secondary essential services. However, cooling and reliquefacation equipment and systems essential to maintain the stored CO_2 temperature and pressure within design limits are considered essential services.

2.3.4 Inclinations

OCCS systems are to be designed for proper operation at the inclination requirements of 1.6.1 of Part IV of the Rules for Steel Ships.

2.3.5 Vibration

OCCS systems are to be designed and installed to avoid the presence of dangerous or detrimental vibration that reduces the safety and reliability of the installed equipment or pose a hazard to the ship or crew. Installed equipment is to be verified to confirm that the limits do not exceed those proposed by the manufacturer.

2.3.6 Ship stability, loading and capacity

(a) For those existing ships 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 CO_2 and OCCS process consumables.

Note:
If the change in lightship displacement from the addition of the OCCS system and all other changes to the ship subsequent to the most recent approved lightship data, exceeds 2% and/or the change in lightship longitudinal center of gravity exceeds 1.0% of the length between perpendiculars, and/or the lightship vertical center of gravity exceeds 1% of the approved value, an inclining test will be required for the ship 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), as amended. 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.

(b) 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 CO_2 and OCCS process consumables, in accordance with 2.3.6(a) above is to be submitted.

2.4 Location of OCCS System

2.4.1 EGC pre-scrubbing/quenching and absorber units

(a) 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.

(b) The location of pre-scrubbing/quenching or absorber EGC units is to be considered by the risk assessment found in 1.4. 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.

(c) See also Chapter 3 for the requirements for pre-scrubbing/quenching and absorber systems.

2.4.2 Desorber or stripping units

(a) 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.

(b) The location of desorber or stripping units and associated auxiliary equipment is to be considered by the risk assessment required by 1.4. 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.

(c) See also Chapter 3 for the requirements for desorber systems.

2.4.3 Solvents and consumables

(a) Locations of any chemicals, solvents, consumables, or process fluids used in the washwater, or CO_2 separation systems are to be based on the hazards of the specific media, required quantities for the installed arrangements and ship operational profile.

(b) These CO_2 separation media are to be considered by the risk assessment required by 1.4. 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.

(c) See also 3.4.3 for the requirements for chemical treatment piping systems.

2.4.4 EGC residues

(a) 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.

(b) See also 3.4.4 for the requirements for the EGC residue system.

2.4.5 CO_2 processing

(a) Equipment for CO_2 gas liquefaction, e.g., compressors, coolers, separators, and dryers is to be located in a dedicated space or compartment.

(b) The location of the CO_2 processing system and associated auxiliary equipment is to be considered by the risk assessment required by 1.4. The risk assessment is to consider, but is not limited to, consequences of CO_2 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.

(c) See also Chapter 4 for the requirements for CO_2 compression, refrigeration, and liquefaction systems.

2.4.6 Liquefied CO_2 storage tanks

(a) Liquefied CO_2 storage tanks may be located on deck or within dedicated CO_2 tank rooms or hold spaces within the ship.

(b) The CO_2 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 ship and other hazards that may be relevant to the ship.

(c) The location of the CO_2 storage tanks and unloading arrangements is to be considered by the risk assessment required by 1.4. The risk assessment is to consider, but is not limited to, consequences of CO_2 release, together with impacts on normal operations, line of sight and emergency access to LSA equipment or escape routes.

(d) See also Chapter 5 for the requirements for CO_2 storage.

2.5 Personal Safety and Personal Protective Equipment (PPE)

2.5.1 Suitable protective equipment is to be provided for protection of crew members engaged in normal OCCS system maintenance and operation.

2.5.2 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 CO_2 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/CO_2/oxygen detectors, suitable eye protection, aprons, rubber gloves, coveralls, footwear, air sets, eyewash and shower facilities. The extent and quantities of required personal safety and PPE are 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 are to be considered by the risk assessment provided in 1.4.

2.5.3 The personal protective and safety equipment required by the risk assessment for the specific ship and OCCS system is to be kept in suitable, clearly marked lockers located in readily accessible locations.

2.5.4 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 2 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.

Note:
For ships of unrestricted service, ambient temperature as indicated in 1.2.3 of Part IV of the Rules for Steel Ships is to be considered in the selection and installation of machinery, equipment, and appliances. For ships of restricted or special service, the ambient temperature appropriate to the special nature is to be considered.

Chapter 3 Pre-Scrubbing/Quenching, Absorber and Desorber Systems

3.1 General

3.1.1 This Chapter provides requirements on the arrangements and system design for the EGC and CO_2 stripping parts of a post-combustion OCCS system covering the pre-scrubbing/quenching, absorber and desorber units.

3.1.2 Where a pre-scrubbing or quenching unit is also designed for the removal of SOx emissions, that unit may be assigned the additional **SOx Scrubber** notation when it has also been verified to be designed, constructed, and tested in accordance with the requirements of the Guidelines for SOx Scrubber Systems (hereinafter referred to as the SOx Guidelines).

3.1.3 Where other exhaust emission abatement equipment such as diesel particulate filters and electrostatic precipitators are utilized independently or in combination with OCCS systems, or where alternative means of CO_2 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 the Society's relevant Guidelines. Such arrangements will be accepted subject to the arrangements being determined by the Society as being not less effective than the overall safety, strength, goals, principles and intent of the requirements of the Guidelines.

Notes:
(1) 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 SOx scrubbing as an equivalent under Regulation 4 for the fuel sulfur limits given by Regulation 14 of MARPOL Annex VI. Where OCCS EGC units are designed for the removal of SOx emissions, they will need to also comply with those statutory requirements.
(2) 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 CO_2 stripping systems.
(3) 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 Bleed-Off Water, adopted 26 October 2018, provides guidance on water discharge quality when using sulfur compliant fuel.
(4) 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 CO_2 stripping systems (open or closed loop) that are designed with bleed or discharge water arrangements.

3.2 Plans and Data

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

(a) General arrangement of the pre-scrubbing/quenching, absorber and desorber installation, layout, and systems.

(b) Documentation detailing the pre-scrubbing/quenching, absorber and desorber specifications.

(c) Analyses demonstrating compatibility of the EGC pre-scrubbing/quenching and absorber units with the fuel oil combustion units. See 2.3.1.

(d) Hull plans showing the foundation and attachments to the ship's structure, including scantlings, welding details, and foundation details of principal components.

(e) Documentation detailing the effect on load line and stability and loading of the pre-scrubbing/quenching, absorber and desorber systems. See 2.3.6.

(f) 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 CO_2 stripping parts of the OCCS system.

(g) Arrangement and capacity of tanks for storage of chemicals, solvents, process washwater, EGC and process residues.

(h) Details of all piping systems, including details of piping and associated components, design pressures, temperatures, insulation, and drip trays.

(i) 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.

(j) Details of all electrical equipment installed for the pre-scrubbing/quenching, absorber and desorber unit(s) and associated systems, including computer-based systems.

(k) FMEA to determine possible failures and their effects in the safe operation of the pre-scrubbing/quenching, absorber and desorber unit(s). See 6.3.2.

(l) ESD arrangements.

(m) 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).

(n) Testing procedures during installation and commissioning trials (to be submitted for survey verification only).

3.3 System Equipment

3.3.1 Pumps/fans

(a) 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 4.5 of Part IV of the Rules for Steel Ships. 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 bore.
If the above thresholds are not met, certification of the pumps used in such systems is not required; however, manufacturer's documents and guarantee shall still be provided for reference and record.

(b) Unless alternative means of compliance in accordance with 2.3.2 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 2 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 3.3.4(c).

For ships fitted with 2 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.

(c) Unless alternative means of compliance in accordance with 2.3.2 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 2.3.1(e).

3.3.2 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 Part V of the Rules for Steel Ships.

3.3.3 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 CO_2 stripping systems, and within the scope of 1.1 of Part V of the Rules for Steel Ships, are to be designed, constructed, and certified in accordance with Part V of the Rules for Steel Ships.

3.3.4 Electrical system

The electrical system and electrical equipment requirements are to be applied in association with the requirements of Part VII of the Rules for Steel Ships.

(a) Electrical motors and controllers

Motors of 75 kW and above and all motor controllers, regardless of motor rating, shall be tested and surveyed separately in accordance with 4.2 and Chapter 9 of Part VII of the Rules for Steel Ships.

(b) 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 11.2.1 of Part VII of the Rules for Steel Ships.

(ii) The electrical loads associated with the OCCS systems are to be included in the electric-plant load analysis required by 1.2.2 (b)(ii) of Part VII of the Rules for Steel Ships.

(c) 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 3.3.1, 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.

(d) 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.

3.4 System Piping

3.4.1 Exhaust gas piping systems

(a) 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 2.13 and 4.8 of Part VI of the Rules for Steel Ships.

(v) Exhaust gas piping and piping components constructed of non-metallic materials are to comply with 2.8 of Part VI of the Rules for Steel Ships and are to be specifically approved for the intended application.

(b) Exhaust gas piping valves

(i) Valves used in the exhaust gas parts of OCCS EGC systems are to meet the requirements of 2.3 to 2.5 of Part VI of the Rules for Steel Ships 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 6.3.2.

(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.

(c) 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 2.3.1(b) and (c).

(ii) In all arrangements, the OCCS EGC system is to be designed so as to not exceed the back pressure 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 2.3.1(e) and 3.3.1(c).

(d) 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 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.

3.4.2 Pre-scrubbing/quenching washwater piping

(a) Piping and connections

(i) In general, pipe fittings and joints are to meet the requirements for tests and inspections in Chapter 7, materials in 2.3, and design in Chapter 2 of Part VI of the Rules for Steel Ships, subject to the limitations found in pipe joints in Fig. VI 4-3 of Part VI of the Rules for Steel Ships.

Molded non-metallic expansion joints, where used, are to be of an approved type (see 2.5 of the Rules for Steel Ships for Cu and Cu Alloy and Table VI 2-5 of the Rules for Steel Ships 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 2.8 of Part VI of the Rules for Steel Ships. For the purpose of the Rules for Steel Ships, "plastic" means both thermoplastic and thermosetting plastic materials, with or without reinforcement, such as polyvinyl chloride and fiber reinforced plastics. Plastic washwater piping is to meet Level 3 fire endurance testing requirements (See 2.8.4 of Part VI of the Rules for Steel Ships).

(iv) Flexible hoses are to comply with the requirements of 2.9 of Part VI of the Rules for Steel Ships.

(b) 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 6.3.2.

(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.

(c) 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 3.1 of Part VI of the Rules for Steel Ships 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 the Society 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 ship 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 2.8 of Part VI of the Rules for Steel Ships.

3.4.3 Chemical treatment systems

(a) 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 the Society on a case-by-case basis and are to be considered by the risk assessment required by 1.4. 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 SOx scrubbing units, the requirements of 3.2.3 of the SOx Guidelines 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:

(i) Piping and tank materials.

(ii) Bulk loading and arrangements.

(iii) Arrangement of tanks.

(iv) Tank filling, vents and overflow arrangements.

(v) Sounding and temperature indication.

(vi) Spill trays.

(vii) Ventilation arrangements.

(viii) Unloading arrangements for residues, spent solvents or solvents intended for onshore processing.

(ix) PPE. See 2.5.

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 the Society to determine if storage is in accordance with these requirements, as applicable to the particular chemical hazards.

(b) 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.

3.4.4 Residue system

(a) CO_2 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. Such residues are not to be discharged to the sea or incinerated on board.

The residue tanks are to be designed to facilitate cleaning.

(b) The material of the residue tanks is to be selected based on the corrosive nature of the residue.

(c) 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.

(d) The residue tanks are to be provided with vent pipes complying with 3.2 of Part VI of the Rules for Steel Ships. 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 ship. Alternatively, the tanks are to be fitted with appropriately sized pressure/vacuum valves.

(e) The residue tanks are to be arranged with a high level alarm.

(f) Sounding arrangements are to be provided for the residue tanks in accordance with 3.4 of Part VI of the Rules for Steel Ships. In addition to local level gauging, residue tanks are to have remote level gauging indication at the control station.

(g) For those ships that do not utilize onboard incineration and collect all engine room sludge for disposal ashore, the Society will consider arrangements utilizing a combined engine room sludge and OCCS residue tank, provided the tank meets the requirements of 3.4.4(a) through (g), 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 6.2.1 of Part VI of the Rules for Steel Ships plus the capacity requirements for residue tanks of 3.4.4(c).

3.4.5 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:

(a) Redundancy of equipment is to be provided for those rotating and reciprocating components that form part of the OCCS ancillary systems in accordance with 2.3.2 and 2.3.3.

(b) Piping design and arrangements are to be in accordance with the applicable requirements of Part VI of the Rules for Steel Ships.

3.5 Monitoring and Safety System Functions

The monitoring and safety system functions are to be in accordance with Table 3-1.

Table 3-1
Monitoring and Safety System Functions for Pre-Scrubbing/Quenching, Absorber and Desorber Systems

Monitored parameters[(1)]	Display	Alarm activated	Automatic shutdown
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)
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	
ESD	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 3.3.4(c) .
(3) Automatic bypass of the OCCS EGC units as per 2.3.1(f).
(4) As applicable to the particular design. See 6.3.5.
(5) Remote closure of the close coupled storage tank valves.

Chapter 4 CO_2 Compression, Refrigeration and Liquefaction Systems

4.1 General

4.1.1 This Chapter provides the requirements for OCCS systems that remove carbon as CO_2 and covers the machinery and equipment plant for separation, compression, cooling, drying and liquefaction of the CO_2 gas and any liquid cooling or reliquefaction systems used to maintain control of the stored CO_2 temperature and pressure. See Chapter 5 for the requirements for liquefied CO_2 storage.

4.1.2 This Chapter is to be applied in association with the applicable requirements of the LGC Guidelines, 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 CO_2 given under 17.21 and 17.22 of the LGC Guidelines for high purity and reclaimed quality CO_2 respectively.

4.1.3 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 CO_2 will also be considered. Such solutions will be considered subject to the arrangements being determined by the Society as being not less effective than the overall safety, strength, goals, principles and intent of the requirements of the Guidelines.

4.2 Plans and Data

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

(a) General arrangement of the CO_2 gas compression, cooling, drying and liquefaction compartment, layout and systems.

(b) Documentation detailing the CO_2 gas compression, cooling, drying and liquefaction specifications.

(c) Schematic diagram of the ventilation system for the CO_2 gas compression, cooling, drying and liquefaction compartment including openings.

(d) Diagram of the fixed CO_2 and O_2 gas detection and monitoring and alarm systems and associated shut-off and shutdown systems.

(e) Details of all piping systems, including details of piping and associated components, design pressures, temperatures and insulation.

(f) Gas compressors.

(g) Filters and dryers.

(h) Pressure vessels, including separators and heat exchangers.

(i) Schematic diagram of the cooling, refrigeration and liquefaction system(s) together with the calculations concerning the refrigerating and liquefaction capacity.

(j) Descriptions and schematic diagrams for the control and monitoring system including set points for abnormal conditions.

(k) Details of all electrical equipment in the CO_2 gas compression, cooling, drying and liquefaction compartment.

(l) Schematic wiring diagrams.

(m) Electric bonding (earthing) arrangements.

(n) FMEA to determine possible failures and their effects in the safe operation of the CO_2 gas compression, cooling, drying and liquefaction plant. See 6.3.2.

(o) ESD arrangements.

(p) Operating and maintenance instruction manuals (to be submitted for reference purposes only).

(q) Testing procedures during installation and commissioning trials (to be submitted for survey verification only).

4.3 System Design and Capacity

4.3.1 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 4.4.

4.3.2 The OCCS compression, cooling, drying, and liquefaction plant is to be designed taking into account the composition of the CO_2 gas stream and expected impurities, including the effect those impurities may have on the triple point temperature of the CO_2.

Note:
The precise triple point temperature of a particular CO_2 gas stream depends on the purity of that CO_2. Refer also to 17.21 and 17.22 of the LGC Guidelines.
The quality and purity of the CO_2 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 CO_2 in the food and beverage industries requires that CO_2 meets the applicable national regulations; however, captured CO_2 for sequestration purposes may be of a lower purity. Currently, no international CO_2 purity standards for CCS systems exist and guidance may be sought from developing standards such as those from the UK's National Physical Laboratory.

4.3.3 The capacity of the cooling or reliquefaction systems required for temperature and pressure control of the stored CO_2 is to be based on the intended CO_2 storage condition and the requirements of 5.4.

4.3.4 Cooling or reliquefaction systems are to meet the redundancy requirements of 2.3.2 and are considered essential services.

4.3.5 The CO_2 gas to liquid process system is to be designed to prevent venting of CO_2 at all times except in emergency situations.

4.3.6 The procedures for overall operation between dry-docking intervals of the CO_2 storage tank(s) and associated compression, refrigeration and liquefaction systems, covering but not limited to, cool down, unloading, gas freeing, pressure/temperature control, ESD, maintenance and inspection are to be included in the operating and maintenance instruction manuals.

4.4 CO_2 Machinery Space

4.4.1 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.

4.4.2 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 2 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 5 m or less.

4.4.3 All ESD valves are to be readily accessible to personnel wearing protective clothing.

4.4.4 The space is to be fitted with an independent mechanical extraction ventilation system providing 30 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 CO_2.

4.4.5 The CO_2 machinery space, and other enclosed spaces where CO_2 may accumulate, are to be fitted with continuous CO_2 gas detection monitoring for CO_2 build up; see also 17.21.6 of the LGC Guidelines.

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 CO_2. See also 6.5.1 for placement of detectors.

An alarm is to be given at the remote-control position(s) and at the local control station if the CO_2 content rises above 4%. Visual and audible alarms are also to be placed at each entrance to the machinery space.

4.4.6 A minimum of 2 oxygen sensors are to be positioned at appropriate locations within the space. See also 6.5.1 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.

4.4.7 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.

4.4.8 Gas detection equipment is to meet the requirements of 6.5.

4.4.9 Warning signs are to be placed where they will be easily seen at the entrances to CO_2 machinery spaces, and other enclosed spaces where CO_2 may accumulate, that warn of the risks of asphyxiation.

4.5 System Equipment

4.5.1 Reliquefaction and refrigeration systems

(a) Reliquefaction and cooling or refrigeration systems are to be designed, constructed, and tested in accordance with the applicable requirements of 7.3 of the LGC Guidelines and Annex 2 for Ships Using Gases or other Low-Flashpoint Fuels (hereinafter referred to as the LFFS Guidelines).

(b) Where the CO_2 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 2.3.2 and availability in accordance with 7.8 of the LGC Guidelines. See also 5.4 for CO_2 storage tank filling limits and pressure/temperature management criteria.

4.5.2 Materials

(a) Materials in general are to comply with the requirements of Part XI and Part XII of the Rules for Steel Ships.

(b) Materials for liquefied gases are to comply and be tested and certified in accordance with the applicable requirements of Chapter 6 of the LGC Guidelines.

(c) 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 CO_2 cleaning and stripping process. See also 17.21.5 and 17.22.1 of the LGC Guidelines.

(d) All materials used in the liquefied CO_2 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 CO_2 at the set pressure of the automatic safety system described in 5.3.4(d).

4.5.3 Compressors

Gas compressors are to be designed, constructed, and tested in accordance with 7.5 of Annex 5 of the LFFS Guidelines.

Motors of 75 kW and above and all motor controllers, regardless of motor rating, shall be tested and surveyed separately in accordance with 4.2 and Chapter 9 of Part VII of the Rules for Steel Ships.

4.5.4 Separators, pressure vessels, and heat exchangers

(a) All separators, process pressure vessels, heat exchangers, filters, and dryers within the scope of 1.1 of Part V of the Rules for Steel Ships, are to be designed, constructed, and certified in accordance with Part V of the Rules for Steel Ships.

(b) Liquefied CO_2 pressure vessels are to be designed in accordance with the requirements for type C independent tanks of 4.23 of the LGC Guidelines.

4.5.5 Pumps

Liquefied CO_2 pumps are to be designed and tested in accordance with 5.13.1.3 of the LGC Guidelines.

4.6 System Piping

4.6.1 Any CO_2 piping is not to pass through accommodation spaces, service spaces or control stations.

4.6.2 Gaseous and liquefied CO_2 piping is to comply with Chapter 5 of the LGC Guidelines.

4.6.3 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.

4.6.4 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.

4.6.5 The piping system is to be installed with sufficient flexibility to accommodate the oscillating movements that may be applicable without risk of fatigue failure.

4.7 Monitoring and Safety System Functions

The monitoring and safety system functions are to be in accordance with Table 4-1.

Table 4-1
Monitoring and Safety System Functions for Compression, Refrigeration and Liquefaction Systems

Monitored parameters(1)	Display	Alarm activated	Automatic shutdown
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)
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	
ESD	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 3.3.4(c).
(3) See 4.4.4.

Chapter 5 Liquefied CO_2 Storage

5.1 General

5.1.1 This Chapter provides the requirements for OCCS systems that store carbon as liquefied CO_2 and covers the requirements for the CO_2 storage tank(s) and associated pressure relief and venting systems. See Chapter 4 for the requirements for CO_2 compression, refrigeration, and liquefaction systems.

5.1.2 This Chapter is to be applied in association with the applicable requirements of the LGC Guidelines for liquefied gas applications and in particular the special requirements for CO_2 given under 17.21 and 17.22 of the LGC Guidelines for high purity and reclaimed quality CO_2 respectively.

5.1.3 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 CO_2, or store CO_2 in a compressed form will also be considered. Such solutions will be considered subject to the arrangements being determined by the Society as being not less effective than the overall safety, strength, goals, principles and intent of the requirements of the Guidelines.

5.2 Plans and Data

5.2.1 Plans, data and specifications covering the liquefied CO_2 storage tank(s) with all the accessories are, as applicable, to be submitted:

(a) General arrangement showing the position of the CO_2 storage tank(s), details of manholes and other openings and, as applicable, hold space arrangements.

(b) Plans of the hull structure in way of the CO_2 storage tank(s), including the installation of attachments, accessories, internal reinforcements, saddles for support and tie-down devices.

(c) Detailed construction drawings of the CO_2 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.

(d) Material specifications for the CO_2 storage tank including attachments, valves, and accessories.

(e) Design loads and structural analyses for the CO_2 storage tank(s) together with complete stress analysis, as applicable, of the hull and CO_2 storage tank(s).

(f) Specifications and plans of the insulation system and calculation of the heat balance.

(g) Procedures and calculations of the cooling down operations.

(h) Details and installation of the safety valves and relevant calculations of their relieving capacity, including back pressure.

(i) Tank pressure and temperature control calculation including pressure accumulation, as applicable, as required by 5.4.3.

(j) 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.

(k) Details and installation of the various monitoring and control systems, including the devices for measuring the level, temperature, and pressure of the CO_2 in the tanks and set points for abnormal conditions.

(l) Schematic diagram of the ventilation system indicating the vent pipe sizes and location of the openings.

(m) Details of the electrical equipment and of the electrical bonding (earthing) of the CO_2 tanks and piping.

(n) Diagram of gas detection systems.

(o) Schematic wiring diagrams.

(p) Welding procedures, stress relieving and non-destructive testing plans.

(q) Construction details of submerged pumps including material specifications.

(r) ESD arrangements.

(s) Operating and maintenance instruction manuals (to be submitted for reference purposes only).

(t) Testing procedures during installation and commissioning trials (to be submitted for survey verification only).

5.3 Liquefied CO_2 Storage Tanks

5.3.1 Design

(a) The storage tank(s) used for liquefied CO_2 storage is to be a type C independent tank designed in accordance with 4.23 of the LGC Guidelines.

(b) The CO_2 storage, pressure relief and control and monitoring systems are to be designed taking into account the composition of the liquefied CO_2, water content and expected impurities, including the effect those impurities may have on the triple point temperature of the CO_2.

Note:

Uncontrolled pressure loss from the CO_2 storage tank can cause dry ice formation and the CO_2 will change from liquid to solid form. The precise triple point temperature of a particular CO_2 gas stream will depend on the purity of that CO_2. Refer also to 17.21.5 and 17.22.1 of the LGC Guidelines.

(c) The CO_2 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 CO_2 at all times, except in emergency situations. See also 5.4 for CO_2 storage tank filling limits and pressure/temperature management criteria.

(d) It is to be possible to gas free the CO_2 storage tanks with permanently fitted piping systems.

(e) The procedures for overall operation between dry-docking intervals of the CO_2 storage tank(s) and associated compression, refrigeration and liquefaction systems, covering but not limited to, cool down, unloading, gas freeing, pressure/temperature control, ESD, maintenance and inspection are to be included in the operating and maintenance instruction manuals .

5.3.2 Materials

(a) Materials in general are to comply with the requirements of Part XI and Part XII of the Rules for Steel Ships.

(b) Materials for liquefied gases are to comply and be tested and certified in accordance with the applicable requirements of Chapter 6 of the LGC Guidelines.

(c) 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 CO_2 cleaning and stripping process and which can cause acidic corrosion or other problems. See also 17.21 and 17.22 of the LGC Guidelines.

(d) All materials used in the liquefied CO_2 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 CO_2 at the set pressure of the automatic safety system described in 5.3.4(f).

5.3.3 Pressure relief and venting system

(a) To protect the CO_2 storage tank(s) from overpressure or under pressure, they are to be provided with pressure relief valves and discharge piping meeting the requirements of Chapter 8 of the LGC Guidelines, with the exception of 8.2.9.2, 8.2.10 and 8.2.15 of the LGC Guidelines, referenced by 5.3.3(b), (c) and (d).

(b) There is a potential for the CO_2 to solidify in the event that a CO_2 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 8.2.9.2 of the LGC Guidelines do not apply. See also 17.21.2 of the LGC Guidelines.

The CO_2 gas from the protective devices of the tank is to be discharged to a safe location on the open deck that are:

(i) Not within 3 m of areas traversed by personnel.

(ii) Not within 6 m of air intakes for machinery (engines and boilers) and all ventilation inlets/outlets.

(c) The discharge (venting) piping system from the CO_2 tank pressure relief valves is not required to comply with 8.2.10 of the LGC Guidelines but is to be designed so it remains free from obstructions that could cause clogging. See also 17.21.3 of the LGC Guidelines.

(d) To avoid clogging, protective screens are not to be fitted to the outlets of the CO_2 tank pressure relief valve discharge piping, hence the requirements of 8.2.15 of the LGC Guidelines are not applicable. See also 17.21.2 and 17.21.3 of the LGC Guidelines.

5.3.4 Instrumentation and monitoring

(a) The CO_2 storage tank(s) are to be provided with means of indicating level, pressure and temperature in accordance with the applicable requirements of 13.1, 13.2, 13.4 and 13.5 of the LGC Guidelines.

(b) The CO_2 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.

(c) The high liquid level alarm is to operate at a level not higher than the maximum filling limit given by 5.4.2 and is to trigger automatic shutdown of the liquefied CO_2 supply line to the storage tank using the ESD valve(s) required by 5.5.2.

(d) As per 5.3.1(b), the CO_2 storage system design, including the instrumentation, is to take into account the composition of the liquefied CO_2, water content and expected impurities, including the effect those impurities may have on the triple point temperature of the CO_2. The set pressure for the alarms and automatic actions described in this Chapter are to be set at least 0.05 MPa above the triple point for the specific composition of CO_2 being carried. The triple point for pure CO_2 occurs at 0.518 MPa absolute and -56.6°C.

(e) The CO_2 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.

(f) If the CO_2 storage tank(s) pressure continues to fall to within 0.05 MPa of the triple point for the specific composition of CO_2 being carried, the monitoring system is to automatically close all liquid and vapor lines using the ESD valves required by 5.5.2 and stop all associated compression, cooling or liquefaction equipment.

(g) As applicable, hold spaces used for the location of CO_2 storage tank(s) are to be continuously monitored for CO_2 build up and oxygen concentration, as per 4.4.5 and 4.4.6. Gas detection equipment is to meet the requirements of 6.5.

See also 5.8 for the requirements for monitoring, control and alarm systems.

5.4 Filling Limit and Pressure/Temperature Control

5.4.1 The CO_2 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.

5.4.2 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 15.1.3 of the LGC Guidelines. The maximum operational loading limit for the CO_2 storage tanks is to be determined in accordance with 15.5 of the LGC Guidelines and is to be included in the operation manuals.

Note:
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 CO_2 temperature and pressure control are fitted. Consideration will be given for type C tank loading limits to be calculated in accordance with 15.5.2 of the LGC Guidelines.

5.4.3 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 ship operating profile. Calculations are to be submitted demonstrating this capability.

5.4.4 The design of any cooling or reliquefaction systems required for pressure and temperature control of the stored CO_2, are to be in accordance with 4.5.1(b).

5.5 Emergency Shutdown (ESD) System

5.5.1 All liquid and vapor line connections, including piping connections for gas freeing and unloading, on the CO_2 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.

5.5.2 All liquid and vapor line connections on the CO_2 storage tank(s) are also to be equipped with remotely controlled 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 5.5.1.

5.5.3 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.

5.5.4 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.

5.5.5 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.

5.5.6 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 Table 5-1

5.5.7 As per 5.3.3(c), a means to isolate the pressure relief valves is to be provided.

5.6 Unloading Arrangements

5.6.1 Suitable unloading manifolds, pipework and control and monitoring systems are to be provided for unloading of liquefied CO_2. Arrangements are to be considered by the risk assessment required by 1.4.

5.6.2 The unloading system is to be designed to prevent venting of CO_2 at all times during unloading operations.

5.6.3 Control of unloading is to be from a safe location and, as a minimum, the CO_2 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 5.5 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.

5.6.4 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.

5.6.5 Local pressure gauges are to be located at the unloading manifold between the shut-off valves and presentation flange.

5.6.6 Liquefied CO_2 pumps are to be designed and tested in accordance with 5.13.1.3 of the LGC Guidelines.

5.6.7 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).

5.7 Portable Tanks

5.7.1 Where portable tanks are used for CO_2 storage, the design is to be equivalent to that for permanent installed tanks as required by 5.3.1(a). Refer to 1.7 for guidance on the acceptance of alternatives.

5.7.2 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 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 5.4.2 is not applicable and tanks are not to be loaded beyond the maximum filling ratio applicable under the IMDG Code.

5.7.3 Portable tanks are to be located in dedicated areas.

5.7.4 Portable tanks are to be secured to the deck while connected to the ship 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 ship characteristics and the position of the tanks.

5.7.5 Consideration is to be given to the effect of the portable tanks on the ship's stability.

5.7.6 Connections to the ship piping systems are to be made by means of approved flexible hoses or other suitable means designed to provide sufficient flexibility.

5.7.7 Control and monitoring systems for portable tanks are to be integrated in the ship's OCCS control and monitoring system.

5.8 Monitoring and Safety System Functions

The monitoring and safety system functions are to be in accordance with Table 5-1.

Table 5-1
Monitoring and Safety System Functions for Liquefied CO_2 Storage Tanks

Monitored parameters(1)	Display	Alarm activated	Automatic shutdown
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	
ESD	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 5.3.4(b) and low liquid level protection in accordance with 5.6.7.
(3) Automatic activation of the supply line ESD valve as per 5.3.4(c).
(4) Automatic activation of the liquid and vapor line ESD valves as per 5.3.4(f).

Chapter 6 Control, Monitoring and Safety Systems

6.1 General

This Chapter 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 VII and Part VIII of the Rules for Steel Ships for electrical and automation systems respectively.

6.2 Plans and Data

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

(a) A general description of the operation of the system is to be provided. This is to include the system configuration, general arrangements for the ship 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.

(b) Details on control stations, local manual controls, instrumentation and communication systems.

(c) 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.

(d) FMEA to determine possible failures and their effects in the safe operation of the OCCS system.

6.3 Control and Monitoring System

6.3.1 The control system for the OCCS system may be connected to an integrated control system or be a stand-alone system.

6.3.2 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 ship.
The FMEA, or equivalent failure analysis methodology, demonstrating the design basis is to be submitted. See also 1.2.2(d) of Part VIII of the Rules for Steel Ships.

6.3.3 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 Chapter 2 of Part VIII of the Rules for Steel Ships, as applicable.

6.3.4 Automatic control, monitoring, alarm, and safety functions are to be provided so that OCCS operations remain within preset parameters for all operating conditions. For ships with **CAS** or **CAU** notations, the alarm and monitoring systems are to be integrated in the ship's centralized monitoring systems that conform to the requirements for **CAS** or **CAU** notations.

6.3.5 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 Tables 3-1, 4-1 and 5-1. 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 CO_2 removal efficiency, CO_2 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.

Note:
Solvent condition monitoring, CO_2 flow rate, % CO_2 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.

6.3.6 Computer-based control systems are to comply with the applicable requirements of Chapter 3 of Part VIII of the Rules for Steel Ships as a Category II system based on Table VIII 3-1 of the Rules for Steel Ships.

6.3.7 The power supply arrangements for the control and monitoring system are electric. Each of the control, monitoring and safety systems is to be supplied by a separate circuit. Each of these circuits is to be protected for short circuit and monitored for voltage failure.

6.3.8 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.

6.3.9 The control and monitoring system is to include compressor anti surge protection.

6.3.10 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 Table VIII 2-2 of the Rules for Steel Ships.

6.4 Safety Shutdown System

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

(a) Means are to be provided to indicate the parameters causing shutdown.

(b) Upon activation of the safety shutdown system, alarms are to be given at the remote-control position(s) and at the local control station.

(c) 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.

6.4.2 Safety shutdowns are to be automatically activated for the conditions in Tables 3-1, 4-1 and 5-1.

6.5 Gas Monitoring and Detection System

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

6.5.2 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 4.4.5, 4.4.6 and 5.3.4(g) for the requirements for CO_2 and O_2 monitoring of CO_2 machinery spaces and CO_2 tank hold spaces.

6.5.3 Gas detection is to be continuous without delay.

6.5.4 Gas detection systems are to be of the self-monitoring type.

6.5.5 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 ESD.

6.5.6 The gas detection equipment is to be designed so that it may be readily tested.

6.5.7 The gas detection system is always to be in operation, during normal operation and while purging prior to maintenance works.

6.5.8 At least 2 portable oxygen level gas detectors are to be provided that meet an acceptable recognized standard.

6.6 Exhaust Emission Monitoring Systems (EEMS)

6.6.1 The intent is that the Society's requirements supplement the statutory specification, calibration, testing, and survey requirements of the applicable IMO Regulations and Guidelines. At the time of publication of the Guidelines the only available IMO instruments are applicable to selective catalytic reduction and SOx scrubber system monitoring. The statutory approval aspects under those IMO instruments, and others that may be developed specifically for OCCS monitoring systems in the future, may be made by the Society 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.

6.6.2 The analyzer specifications and calibration of emissions analyzers installed for the purposes of monitoring CO_2 concentrations or other process gases, or impurities are to be in accordance with the requirements of the following:

(a) The EEMS gaseous analyzers are to be in accordance with the principles and specifications of Appendix 3 of the NOx Technical Code or else demonstrated as equivalent in accordance with ISO 5725-1 and 5725-2, as permitted by 5.4.2 of the NOx Technical Code and Chapter 7 of ISO 8178-1.

(b) Calibration of the EEMS analyzers is to be in accordance with Appendix 4 of the NOx Technical Code or else technical specifications demonstrated as equivalent.

6.6.3 Sample probes for gaseous emissions monitoring of CO_2 concentrations or other process gases or impurities are to be in accordance with the requirements of the following:

(a) The gaseous sampling probes are to be positioned to enable sampling of a representative exhaust gas sample after the engine, turbocharger, or EGC system, in accordance with the location and temperature criteria of 5.9.3.1 and 5.9.3.2 of the NOx Technical Code.

Sample probes are to meet the design requirements of 1.2.1 of Appendix 3 of the NOx Technical Code.

(b) A sample probe connection flange designed in accordance with Chapter 5 of Appendix 8 of the NOx Technical Code and the specification of 6.6.3(a) above is to be provided for each engine required to be monitored.

(c) The sample probe connection flanges are preferably to be installed in accessible locations, clear of or protected from obstructions or moving equipment, in order to permit regular inspection and/or periodic servicing.

(d) In order to establish the capability of the sample probe to withstand fatigue, which is likely to occur due to vibrations under operating conditions, each sample probe design is to be vibration tested in accordance with a recognized standard.

Chapter 7 Surveys and Maintenance of Class

7.1 General

7.1.1 This Chapter is concerned with survey during construction and periodical surveys after construction for the equipment described in Chapters 1 to 6.

7.1.2 The OCCS systems are to be tested and certified in accordance with relevant requirements of the Guidelines, the Rules for Steel Ships, and the Guidelines for Survey of Products for Marine Use. Certification of the complete OCCS system is required; therefore, the Surveyor's attendance during fabrication is necessary for certification.

7.1.3 In addition to the provisions of the Guidelines, the OCCS system is to meet the relevant requirements of applicable Rules and standards.

7.1.4 Modifications

(a) 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.

(b) If the Society 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 the Guidelines.

7.2 Survey during Construction

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

(a) 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.

(b) Piping systems are to be visually examined and pressure-tested, as required by the Rules for Steel Ships. Pressure tests conducted on Class I piping (See Fig. VI 1-1 & Table VI 1-1 of the Rules for Steel Ships) systems are to preferably be recorded on test charts for the duration of their tests.

(c) Electrical wiring and connections are to be in accordance with Chapter 8 of Part VII of the Rules for Steel Ships and checked for continuity and proper workmanship.

(d) Instrumentation is to be tested to confirm proper operation as per its predetermined set points.

(e) Pressure relief and safety valves are to be tested.

(f) Control system and shutdowns are to be tested for proper operation. Functional testing of alarms for monitoring and safety functions with reference to Table 3-1, 4-1 and 5-1, as applicable, is to be carried out. The operational testing is to be carried out to the Surveyor's satisfaction to demonstrate the level of redundancy established by the FMEA.

(g) The OCCS units are to be checked for proper operation in accordance with the submitted installation test procedures.

(h) Availability of operation manuals, trial test procedures/results of trials and FMEA onboard is to be verified.

7.2.2 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 trials.

7.3 Survey after Construction

7.3.1 Annual survey

At each Annual survey, the following requirements are to be complied with:

(a) The OCCS units and systems (e.g. pumps, compressors, pressure vessels, CO_2 piping system) are to be checked for proper operation in accordance with the submitted test procedures and operation manuals.

(b) Functional testing of alarms for monitoring and safety functions with reference to Tables 3-1, 4-1 and 5-1, as applicable, is to be carried out as far as practicable and reasonable.

(c) Testing of portable oxygen level detectors.

(d) Examination of all other personnel safety and PPE specific to the OCCS systems.

(e) Instrumentation, control, monitoring, gas detection and safety systems including verification of the calibration.

7.3.2 Intermediate survey

At each Intermediate survey, all the requirements for annual survey are to be complied with.

7.3.3 Special survey

(a) At each Special survey, all the requirements for annual survey are to be complied with.

(b) The main components and equipment of the OCCS installation are to be examined to the satisfaction of the Surveyor at the special 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 CO_2 machinery space arrangements including ventilation systems.

(v) Compressors, dryers, separators, heat exchangers, pumps and equipment for compression and liquefaction of the collected CO_2 and temperature/pressure control.

(vi) The CO_2 storage tanks and associated valves, pumps, piping and unloading arrangements.

(vii) Electrical equipment.

(viii) Functional testing of alarms for monitoring and safety functions with reference to Tables 3-1, 4-1 and 5-1, as applicable.