Emission Capture and Control at Berth:

Preliminary Safety Recommendations

(First edition January 2025)

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The Oil Companies International Marine Forum (OCIMF)
Founded in 1970, the Oil Companies International Marine Forum (OCIMF) is a voluntary association of oil companies having an interest in the shipment and terminalling of crude oil, oil products, petrochemicals and gas, and includes companies engaged in offshore marine operations supporting oil and gas exploration, development and production.

Our vision is a global marine industry that causes no harm to people or the environment.

Our mission is to lead the global marine industry in the promotion of safe and environmentally responsible transportation of crude oil, oil products, petrochemicals and gas, and to drive the same values in the management of related offshore marine operations. We do this by developing best practices in the design, construction and safe operation of tankers, barges and offshore vessels and their interfaces with terminals and considering human factors in everything we do.

Contents

Glossary

Barge A floating platform for Emission Capture and Control (ECC) operations.

Barge's Concept of Operations A document that describes comprehensive measures adopted to enable the ECC barge to operate safely with tankers and terminals. This document should be based on a detailed operational risk assessment.

Boiler Combustion Control (BCC) system A system that manages the fuel and air supply to a boiler to ensure efficient and safe combustion. It minimises unburnt fuel and prevents hazardous conditions, such as fuel-rich atmospheres, within the firebox and exhaust stream. The BCC system typically includes safety features like purging cycles to clear the firebox of flammable mixtures before reignition after a flame failure.

Boom A structural element on the ECC barge that supports and positions the ECC collector over a tanker's funnel and exhaust stacks.

CARB At Berth Regulation The Control Measures for Ocean-Going Vessels At Berth, sections 93130 to 93130.22 of Title 17 of the California Code of Regulations.

Collector One or more devices positioned over a vessel's exhaust stacks to collect exhaust gases and channel them into the ductwork. It is the interface between the ECC barge and the vessel's exhaust stacks.

Compatibility studies These studies evaluate the compatibility between the ECC barge, the tanker, and the terminal. Examples include verifying the suitability of the ECC positioning with the tanker and terminal mooring system and assessing the compatibility between the tanker's exhaust stack and the ECC collector.

Ductwork A series of conduits that transport captured exhaust gases from the collector to the treatment equipment on the ECC barge.

Emission Capture and Control (ECC) A system designed to capture and treat exhaust gas from tankers at berth to reduce Nitrogen Oxides (NOx), Particulate Matter (PM) and Reactive Organic Gases (ROG) emissions.

Exhaust gas collection apparatus The apparatus serves as the interface between the tanker and the ECC system, enabling the transfer of the tanker's emissions to the treatment system. Its components include the boom, the collector, and the ductwork.

Exhaust gas treatment system Equipment used to treat pollutants in exhaust gases emitted by ships. These systems typically include components such as Diesel Particulate Filters (DPFs) to capture soot and particulate matter, Selective Catalytic Reduction (SCR) units to convert nitrogen oxides into harmless nitrogen and water vapour, and other filtration or chemical treatment processes to remove or neutralise toxic substances. The primary goal of exhaust gas treatment systems is to ensure that the emissions released into the atmosphere are within environmentally acceptable limits.

Exclusion zones Designated areas around the ECC barge and tanker where certain activities are prohibited.

Funnel The ship's exhaust structure, which may incorporate multiple exhaust stacks for different systems (e.g. boilers, main engine, auxiliary engines). It directs exhaust gases away from the ship.

Hazardous atmospheres Environments where there is a risk of fire, explosion, or toxic exposure due to hazardous substances like flammable gases or vapours.

Hazardous areas and hazardous zones Hazardous areas are any place on a terminal or tanker where a sufficiently explosive atmosphere may occur. A hazardous zone is a classification designation found within a hazardous area. It is determined by an assessment based on the frequency of the occurrence and duration of an explosive gas atmosphere.

Inert Gas System (IGS) Used on tankers to prevent explosions and fires in cargo tanks by creating an atmosphere with insufficient oxygen to support combustion. It consists of a gas producer and a scrubbing system that together produce inert gas, typically with less than 5% oxygen content. The system can also use the exhaust gases from boilers, internal combustion engines, or even nitrogen generators to provide the inert gas. This inert gas is then spread over the flammable cargo, creating a non-explosive atmosphere inside the tank.

Minimum Safe Manning Document (MSMD) The document that contains the required number and respective qualifications of ECC crew and personnel.

Metocean conditions Meteorological and oceanographic conditions, such as tides, currents and waves, that affect the operation of vessels and ECC barges.

Offshore terminals Facilities located away from the shore, typically used for the loading and unloading of oil, gas, or other liquid bulk cargo from tankers. These include Single-Point Moorings (SPMs), where vessels are moored to a single buoy that allows them to pivot around it, and Multi-Buoy Moorings (MBMs), where vessels are secured to multiple buoys for added stability. Offshore terminals are often used in deeper waters and are designed to handle large tankers that cannot easily access traditional port facilities.

Position keeping The method used to maintain an adequate relative position between the ECC collector and the tanker's funnel and stacks.

Process Safety Critical Equipment (PSCE) Equipment whose failure could lead to significant accidents involving hazardous substances, fire or explosion.

Safety Management System (SMS) A formal, documented system or framework designed to manage safety in the workplace on shore or a ship. An SMS will include policies, objectives, plans and procedures, as well as organisational responsibilities for those involved in ensuring the system is effectively implemented. For ship activities, an SMS is a requirement of the ISM Code.

Selective Catalytic Reduction (SCR) Using a catalyst, these systems chemically convert nitrogen oxides into nitrogen and water vapour.

Spud A vertical steel shaft used to anchor a barge to the seabed. The system may require penetration of two to four spuds in the seabed to keep the barge stationary during operations.

Stack An individual pipe or duct within the funnel structure through which exhaust gases from a specific piece of equipment are discharged. A funnel can have multiple stacks.

Statement of Terminal Operating Limits (STOL) A document outlining the operational limits of a terminal, including safety boundaries and no-go zones for vessels and equipment like ECC barges.

Station keeping The method used to maintain the ECC barge in a stable position relative to the tanker.

Support vessels The vessels that provide support to the ECC operation, including tugboats used to support the ECC barge manoeuvring and harbour craft used for ECC crew change.

Abbreviations

ALARP	As Low As Reasonably Practicable
BCC	Boiler Combustion Control
CAECS	CARB Approved Emissions Control Strategy
CARB	California Air Resources Board
CO	Carbon Monoxide
CO_2	Carbon Dioxide
DPF	Diesel Particulate Filters
ECC	Emission Capture and Control
H_2S	Hydrogen Sulphide
IGG	Inert Gas Generator
IGS	Inert Gas System
IMO	International Maritime Organization
ISGOTT	International Safety Guide for Oil Tankers and Terminals
ISM Code	International Safety Management Code (IMO)
LSA	Life Saving Appliances
MSMD	Minimum Safe Manning Document
NOx	Nitrogen Oxides
OCIMF	Oil Companies International Marine Forum
PM	Particulate Matter
PPE	Personal Protective Equipment
PSCE	Process Safety Critical Equipment
ROG	Reactive Organic Gases
SCR	Selective Catalytic Reduction
SIMOPS	Simultaneous Operations
SMS	Safety Management System
SOx	Sulphur Oxides
SOP	Standard Operating Procedure
STOL	Statement of Terminal Operating Limits
VHF/UHF	Very High Frequency/Ultra High Frequency (radio systems)

Bibliography

Control Measures for Ocean-Going Vessels at Berth, California Code of Regulations Title 17, Sections 93130 to 93130.22

International Safety Guide for Oil Tankers and Terminals (OCIMF)

International Safety Management (ISM) Code (IMO)

Mooring Equipment Guidelines (OCIMF)

Principles of Minimum Safe Manning, Resolution A1047(27) (IMO)

Requirements for All Transfer Operations, California Code of Regulations Title 2, Section 2340

Safety Critical Equipment and Spare Parts Guidance (OCIMF)

Standard Marine Communication Phrases, Resolution A.918(22) (IMO)

1 Introduction

1.1 Purpose and scope

The adoption of Emission Capture and Control (ECC) can bring environmental advantages to maritime operations in ports and terminals. By using ECC while at berth, ships can reduce their emissions, contributing to improved local air quality and aiding in compliance with environmental regulations.

The Ocean-Going Vessels at Berth Regulation from the California Air Resources Board (CARB), hereunder referred to as CARB At Berth Regulation, prescribes that vessel operators shall use a CARB Approved Emissions Control Strategy (CAECS) to reduce auxiliary engine and auxiliary boiler emissions while a vessel is at berth.

To receive CARB approval, the emission controls strategy must show that it achieves the required emission rates for Nitrogen Oxides (NOx), Particulate Matter (PM) and Reactive Organic Gases (ROG) stated within the regulation.

The vessel operator and the terminal may use a CARB-approved shore-based or barge-mounted ECC system to meet the CARB emissions control requirements.

To aid the safe use of ECC, OCIMF has assembled a workgroup composed of industry experts from different organisations representing shipowners, terminals and classification societies. The workgroup is developing guidance for the safe application of ECC for tankers at berth, considering the interfaces between the ECC technology, the tanker and the terminal.

In the meantime, OCIMF has produced this interim information paper, which aims to provide minimum functional requirements for the safe application of barge-based ECC to oil, chemical and oil product tankers operating at onshore conventional berths, such as piers, jetties and quays.

This paper highlights critical risks and technical and operational challenges and identifies potential preventive measures to safely apply a barge-based ECC.

Gas carriers, offshore vessels, barges and other non-tanker ship types are outside the scope of this work. Similarly, applying ECC to tankers at anchorage, operating at offshore terminals, performing double-banking or ship-to-ship, or using alternative fuels is outside the scope of this work. Still, some of the principles contained in this paper may apply to those ship types and operations and to shore-based ECC.

This interim paper does not:

- Dictate design details.
- Replace the need for site-specific risk assessment.
- Replace a comprehensive design, engineering and operational review.
- Establish a standard to be used for certification.
- Address commercial arrangements, such as who will hire the barge and who will receive the emissions reporting and pricing mechanisms.

An OCIMF guide covering additional aspects of the safe application of ECC to tankers, including the management of interfaces, will follow this paper.

1.2 Overview of a barge-based ECC system

A barge-based ECC system is a mobile solution that captures vessel exhaust gas at the stack to remove NOx, PM and ROG through the use of selective catalytic reduction and filtration technologies. While the design and components can differ among ECC barges, the system consists of three fundamental elements: the barge, the exhaust gas collection apparatus and the treatment system (see figure 1.1).

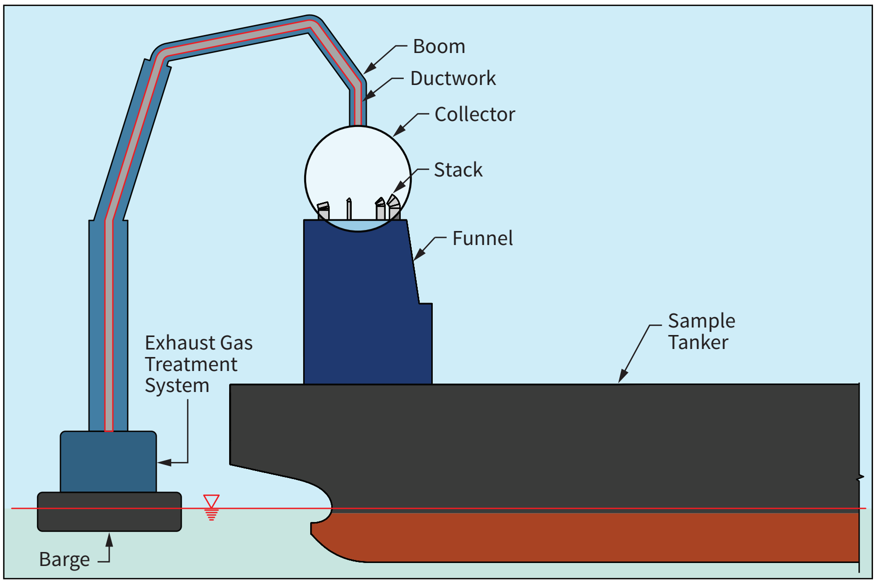


Figure 1.1: *ECC System Primary Components*

The following overview provides a general understanding of the system's functionality.

1.2.1 Barge

The barge acts as a mobile base, allowing the ECC to be positioned near tankers at berth. It is the platform for all equipment required for emissions capture and treatment and vessel station-keeping. Figure 1.2 shows examples of positions that may be considered for the ECC barge depending on site-specific characteristics and constraints.

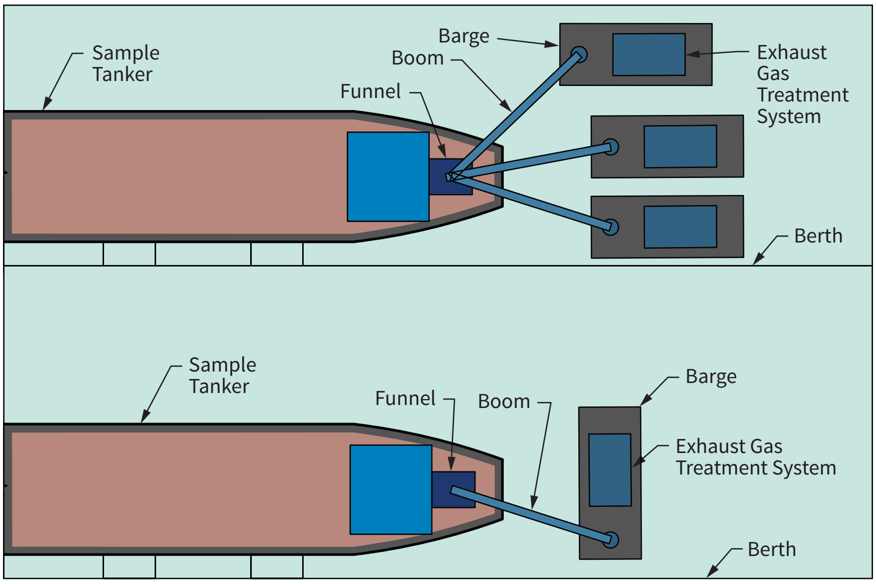


Figure 1.2: *Example of ECC Barge Positions. The ECC barge may be stationed in one of the positions above*

1.2.2 Exhaust gas collection apparatus

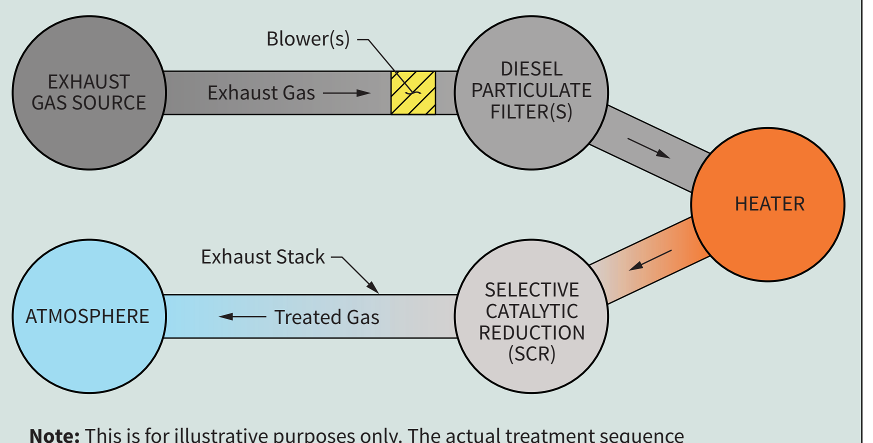
The exhaust gas collection apparatus enables the transfer of the tanker's emissions to the barge's treatment system. The components include:

- Collector: one or more devices positioned directly over the vessel's exhaust stacks to collect exhaust gases and channel them into the ductwork. It is the interface between the ECC barge and the vessel's exhaust stacks.
- Ductwork: a series of conduits that transport the collected exhaust gases from the collector to the barge's treatment system.
- Boom: supports the weight of the ductwork and the collector and positions the collector over the vessel stacks.

1.2.3 Exhaust gas treatment system

At the core of the ECC system is the exhaust gas treatment equipment, which treats the exhaust stream from the tanker's auxiliary engines and boilers. While designs may vary among operators, the following components are typically involved:

- Blower(s): one or more induced flow fans used to draw suction through the system and out through the vent without causing excessive vacuum or backpressure that may upset upstream systems. Control of these fans may be automated based on collector temperature, pressure, process efficiency, ammonia slip, etc.
- Diesel Particulate Filters (DPF): filters designed to trap particulate matter present in the exhaust stream.
- Heater: elevates the exhaust gas temperature to optimal levels for catalytic reaction. It may be a direct-contact flame type or electric.
- Selective Catalytic Reduction (SCR) systems: A system that reduces NOx emissions in the exhaust stream. A reductant, typically ammonia or urea, is injected into the exhaust stream before passing through a catalyst. The catalyst facilitates the chemical reaction that reduces NOx into nitrogen (N_2) and water (H_2O).
- Exhaust stack: a pipe or duct at the end of the gas treatment system that releases treated, but still hot, exhaust gas into the air. When choosing where to place and how to build the stack, ECC designers should consider factors like high temperatures, gas flow rate and how hazardous gases might disperse with different barge/tanker relative positions and wind directions. The stack should be positioned so the exhaust gas does not affect areas where crew members are likely to be or the tanker's ventilation intakes are located. It might be helpful to have two stacks, allowing operators to select the one that best fits the current conditions.



Note: This is for illustrative purposes only. The actual treatment sequence and stages can be different depending on ECC system.

Figure 1.3: *Example of exhaust gas treatment system process. The actual treatment sequence, stages, and components may vary depending on the ECC system*

2 Considerations for explosive atmospheres

This section describes the potential risks associated with the design and operation of an ECC barge in areas where explosive atmospheres may exist or could become present. It identifies critical threats and associated functional requirements.

The ECC barges and support vessels should operate outside the tanker and terminal hazardous areas unless designed and certified to operate safely in a hazardous area.

The ECC barge should have an approved hazardous area plan, and its design should comply with the requirements outlined in that plan.

Abnormal conditions at the terminal or tanker may create an explosive atmosphere where the barge is positioned. In these conditions, the ECC barge should have control measures to prevent ignition sources.

In all cases, the barge operator should demonstrate that the crew's safety is maintained in a hazardous atmosphere, for example, by having a designated pressure-controlled room.

In any scenario, the barge should not prevent the tanker from vacating the berth within the regulatory maximum time (see section 6).

Threats to be considered include the following:

- The entry of non-hazardous-rated barge components, including the boom, within hazardous areas of the tanker or terminal.
- Potential fire or explosion due to the use of non-rated equipment in a hazardous area.
- The presence of non-hazardous zone components of the barge within the hazardous areas during an oil spill/loss of cargo containment.

2.1 Preventive measures

Preventive design and operational measures include the following:

- Pre-arrival communication should include sharing the tanker and terminal hazardous areas with the ECC barge. The ECC barge operator should share the ECC barge hazard area drawing with the tanker operator and terminal operator.
- Use of hazardous-rated equipment or mechanisms to have enough clearance to the hazardous areas for the entirety of the vessel call. See section 5 for further details on defining a safe position for the ECC barge.
- ECC barge needs to provide a detailed concept of operations to tanker and terminal, including specific and localised hazard area zones.
- ECC barge to define the route for placement and removal of the boom, in addition to a position monitoring/motion compensation system and programmable engineering interlocks to maintain the boom outside the hazardous zone.
- The competency training of the barge's crew should include familiarisation with the terminal and tanker's hazardous zones.
- ECC barge should establish safe operational limits considering metocean conditions for connection/disconnection and operation.
- ECC barge should have a fixed hazardous gas detection system at the barge's deck level to trigger shutdown/evacuation.
- A qualified independent party should conduct a risk assessment considering hazardous gas leakage scenarios on the tanker, terminal or barge. This assessment may include a gas dispersion analysis and should consider all components and operational conditions, following recognised risk assessment industry standards.

3 ECC collector, boom and ductwork design and compatibility

The objective of the ECC collector, boom, and ductwork design is to ensure these components are compatible with varying tanker exhaust configurations while maintaining safety, functionality and efficiency in all operating conditions.

3.1 ECC collector design

Funnel casing and stack arrangements are not standardised across ships, which makes designing collectors more complex. Collectors for tankers need to capture exhaust gas from multiple stacks, unlike the single-stack emissions seen on container carriers and roll-on/roll-off ships.

The ECC collector should be designed to provide a safe means of collecting exhaust gas from the intended source without affecting the upstream process of the source. The ECC collector should also not affect surrounding sources and their upstream processes. Volumetric flow rates and pressure from the exhaust source need to be factored into the design of the ECC collector to avoid creating backpressure on the exhaust source. Backpressure should be avoided in all operating and emergency scenarios.

A classification society should verify and approve the ECC collector's design, materials, and construction. See section 15 for more details on barge design and construction verification recommendations.

The positioning of the ECC collector, including during deployment and retraction to the vessel's exhaust sources, is to be performed remotely without boarding the ship (see section 4). Instrumentation used to support the collector positioning should comply with the following:

- Be rated for the operating environment.
- Function under all planned operating scenarios, which may include fog, rain and nighttime operations.
- Do not interfere with the exhaust sources or surrounding objects.

The design criteria and collector operating limits, including metocean conditions and changes in the tanker's draft, should be provided and readily available to the operators. The ability to accommodate such movements should not rely solely on direct human intervention. Operating tolerances should be defined to prevent unintended contact of the collector with the vessel, barge or personnel (see section 4). Operating tolerances should also prevent unintended contact among the collectors if multiple collectors are used. At no time should the operating tolerances be exceeded.

3.2 ECC boom design

The ECC boom design should ensure safe operation when lifting, deploying, and retracting the collector and associated ductwork. It should enable adequate collector positioning without interfering with tanker and terminal operations and be able to function effectively under both normal and emergency conditions.

The tanker's cranes should not be used to lift, manoeuvre or maintain the collector's position.

The boom should be equipped with adequate lighting to ensure visibility along the entire length of the lifting device, from base to tip. The design should also allow clear visibility of the collector to facilitate the management and monitoring of its deploying, positioning and retraction.

The base of the lifting device should be structurally designed to provide support and stability to the lifting device throughout its capable range of motion.

The ECC boom should be designed to allow both manual operation and automatic adjustment to compensate for changes in the tanker's draft during cargo operations (see section 4). It should be designed, built and tested according to the standards of recognised classification societies.

Safety features like trips, alarms, mechanical and electrical safeguards, and redundancies should be included to ensure safe operation.

Regular inspections, maintenance and testing should be scheduled, and the ECC operator should document all results.

A certified third-party organisation, such as a classification society, should carry out an annual certification of the boom.

3.3 ECC ductwork design

The ductwork should provide a non-restricting flow path for exhaust gas between the collector and the treatment system. Volumetric flow rates and pressure from the exhaust source need to be factored into the transfer duct design to avoid creating backpressure on the exhaust source. The exhaust source's backpressure tolerances should not be exceeded.

The materials used to construct the collector should be compatible with the chemical composition of the exhaust source, exhaust temperatures, exhaust flow rates and ambient operating conditions. The ductwork should be insulated, and the material used for insulation should consider the operating parameters, including environmental conditions, under which the ductwork operates.

The ducting should be adequately supported throughout its path between the collector and the treatment system. Any ducting used to transfer exhaust gas from the exhaust source between the collector and the treatment system should not hinder the operation of the lifting device. Operation of the lifting device should not pinch, stretch, twist, or exceed the design tolerances of the ducting. Ducting should not freely hang between the collector and treatment unit and should be adequately secured to prevent interference with the lifting device, barge or tanker operation.

4 Safe positioning of the ECC collector to the tanker stacks or funnel

This section details the risks and functional requirements associated with the positioning of the ECC collector and lists measures for the safe operation of the ECC barge.

The operation of the ECC system should not damage the tanker's structure under any operating or emergency scenario. Unintended contact between the collector and the tanker's structure should always be avoided. If contact between the ECC collector and the tanker stack or funnel is necessary, the ECC provider should demonstrate that such contact will not cause damage to the tanker. This configuration should not prevent the tanker from vacating the berth within the regulatory maximum time (see section 6).

The ECC operator should develop tanker-specific lifting and positioning plans that address measures to safely conduct the collector deployment process, considering risks to people and the tanker's equipment.

Before each operation, the ECC operator should define and document the ideal position of the ECC collector in relation to the tanker's funnel or stack. The tanker should be informed of this position during pre-arrival communications.

The positioning of the ECC Collector, including during deployment and retraction to the ship's exhaust sources, is to be performed remotely without boarding the tanker. Remote monitoring should be used to track the ECC collector position to the tanker's stack or funnel. Periodic checks of the relative position of the collector are recommended but should not be the only way of position-keeping. These periodic checks should be done without personnel accessing the tanker's stack and with minimal interference to the tanker's normal operations. Securing or attaching the collector to the tanker's structure is unacceptable for position-keeping.

The following threats related to the safe positioning of the ECC collector should be considered and mitigated:

- System failure causing the ECC collector to move unexpectedly.
- Operator error causing the ECC collector to move unexpectedly.
- Lack of visibility due to night operations, fog, rain or other adverse conditions.
- Lack of visibility due to barge movement under adverse metocean conditions.
- Lack of visibility due to no direct line of sight.
- Miscommunication between different parties.

4.1 Preventive measures

Preventive design and operational measures include the following:

- ECC barge should develop and communicate the plans for deploying, positioning, and removing the collector for each tanker ahead of each operation. Such a plan should also include a list of engineering safeguards, such as position monitoring/motion compensation systems and programmable engineering interlocks, to avoid contact with the tanker.
- Line of sight, barge and tanker deck watchkeeping, and situational awareness should be maintained throughout the tanker call.
- Adherence to established communication protocols between all parties (see section 16).
- The barge's crew should be trained and competent to place and remove the collector under normal and adverse conditions.
- Crew to perform drills considering the placement and removal of the collector.
- Compatibility studies to assess the interface between the ECC collector and the tanker's funnel or stacks.
- Adequate lighting.
- Metocean conditions monitoring and weather forecast for the operational period.

5 Barge's manoeuvring and station-keeping, including emergency scenarios

ECC barges may have a high air draft and windage area. Before operations, the ECC barge may need to manoeuvre and maintain a station near the tanker. Such manoeuvrings may occur during the day or night and in all weather conditions to meet the demands of 24/7 terminal operations.

The ECC barge should be able to approach and depart safely under normal and emergency scenarios. For that, the following should be considered:

- Availability of assist tug with sufficient power, including extra personnel to support (un)mooring operations.
- Self-propulsion system on ECC barge with sufficient power and steering capability, appropriate staffing and competent crew to manoeuvre the barge.

In all conditions, the barge should not prevent the tanker from vacating the berth within the regulatory maximum time (see section 6).

The ECC barge may moor against the tanker, terminal or dedicated structure, deploy spuds, jack-up, or other position-keeping scheme(s) for station-keeping. Each option imparts varying risks that need to be incorporated into site-specific risk assessments and tanker compatibility studies of the ECC barge operations. The ECC barge position should not obstruct the tanker's ability to launch a lifeboat or life raft, nor should it be positioned below the tanker's overboard discharges.

If the barge is moored to the tanker, terminal or dedicated structure, a mooring arrangement compatibility study should be performed for all berths and ship types, including an update to the berth mooring analysis operating parameters.

A site-specific risk assessment should be completed to determine the ECC barge's safe position during tanker berthing and unberthing. This assessment should also consider passing ships, adjacent terminal operations, cargo operations and other factors.

For multi-modal terminals, there could be an added risk of contact with loading crane(s) operating in the area.

The scenarios to be considered when identifying and addressing risks should, as a minimum, include:

- Potential risk of collision/allision during arrival, operation or departure of the ECC barge with the following:
  - Berthed tanker.
  - Passing ship.
  - Third-party tug/vessel.
  - Fixed structure/bridges.
  - Fixed or mobile cranes nearby.
- Station-keeping system failure, including as appropriate:
  - Mooring system failure such as a mooring line breakage or mooring hook release resulting in drift.
  - Inadequate spud design for ECC barge resulting in drift, excessive bending and pinching of spuds in their wells.
  - Failures of spud deployment and retrieval equipment can result in the potential inability to move the barge and, hence, restrict the ship's ability to move away from the berth during an emergency.

5.1 Preventive measures: design considerations

ECC barge design and engineering should be suited to the metocean conditions, passing ship effects and operational conditions explicitly expected for the terminal.

Safe operational limits should be established for the approach, station-keeping, boom deployment, operation, boom retraction and departure of the ECC barge. These limits should be well documented and communicated broadly.

Tug assistance should be considered to reduce the potential for collision/allision during manoeuvring and emergency scenarios.

If the barge is to moor alongside the terminal or dedicated structure, a fendering system should be appropriately designed and implemented.

If a spudded or jack-up barge solution is selected, local approvals should be considered. Bathymetric or underwater surveys of the affected areas of operations should be maintained.

A secondary means of deploying and retrieving spuds should be considered in case of primary equipment failure.

The ECC barge should have navigation lights, adequate lighting and signalling mechanisms for high visibility during manoeuvring, station keeping, and operational monitoring.

5.2 Preventive measures: operational considerations

Operating and emergency response procedures should be developed and agreed upon before operations.

Training and competency assessments of the barge crew, including terminal and tanker familiarisations, should be considered to ensure safe operations. Periodic drills should also be conducted to support safe operations. See section 10 for further guidance on the required competency and training of ECC personnel.

Before the tanker arrives at and departs from the terminal, the ECC barge should test the equipment associated with all manoeuvring gear (engine and steering gear) and document the results.

Before and during operations, all parties should adhere to communication protocols in a common language, including the definition of nonverbal communication signs and emergency protocols. Pre-arrival and pre-operational information exchange should be conducted between the tanker, terminal and barge, including pre-operational safety checklists. See section 16 for more information on communication protocols.

Monitoring systems and procedures should be maintained during operations. This should include the following:

- Barge, tanker, and terminal watchkeeping.
- Collector position monitoring and management (see section 3).
- Metocean conditions monitoring and weather forecast.
- Regular mooring systems checks.
- ECC system checks.

Additional preventive measures may include assurance processes for the ECC barge, such as inspection and certification of the barges, either from classification societies (see section 15) or Port State Control inspections and site acceptance trials.

If the barge is moored to the tanker, terminal or dedicated structure using mooring lines, the barge should have a mooring line management plan developed as per the *Mooring Equipment Guidelines* recommendations.

6 Tanker departure in case of an emergency

This section provides guidance for tankers and ECC barges in case an immediate unberthing of a tanker is required due to an emergency. Emergency departure should consider the safety of personnel, the environment, the tanker, the ECC barge, and the terminal.

Local authorities regulate the maximum time allowed for a tanker to depart from the berth in an emergency. For example, California Code of Regulations Title 2, § 2340 establishes the maximum allowed departure time as 30 minutes.

In all conditions, the ECC barge should not impede the tanker from rapid disconnection and vacating the berth within the regulatory maximum time. The ship-specific compatibility study should include a plan and procedure for tanker emergency departure, which should be communicated to the tanker before arrival. The emergency communication protocol, procedure, roles and responsibilities should be agreed upon before each tanker operation (see section 16).

The ECC barge should maintain a state of readiness during operations. ECC operators should demonstrate that sufficient competent personnel are always available onboard the barge to perform all actions associated with emergency disconnection, unmooring and movement.

Situational awareness is essential, including monitoring the surrounding area and being aware of the positions and movements of nearby ships.

In normal and emergency situations, the ECC barge should be able to deploy and retract the collector remotely, clearing the tanker without sending people onboard.

The barge's crew should be trained to perform emergency disconnection safely and quickly, including emergency disconnection scenario drills to assess the effect of a real-world incident and ensure crew readiness.

It should be ensured that all the essential ECC barge equipment for the manoeuvre is in good working condition and possesses the necessary capacity to move away from the tanker.

The departure of the ECC barge leaving the collector on top of the tanker funnel is not acceptable. The ECC barge provider should demonstrate that the collector can be withdrawn from the tanker under normal and emergency conditions.

To ensure effective coordination and alignment between the ECC barge, tanker and terminal, the Terminal Information Booklet and the Barge's Concept of Operations should be consistent.

7 Potential effects on tanker machinery and ECC technology

Tanker ships' machinery systems are designed to direct exhaust gases safely away from the vessel with minimal flow obstruction. Introducing ECC collection equipment to the funnel or stack may have unintended consequences for the ship and the ECC technology. These include issues regarding personnel safety, equipment damage, potential failures and explosions, environmental effects and impairment to the operational integrity of the vessel.

The funnel on a typical tanker is an outlet for various systems, each with its discharge point. The following list provides a snapshot of the systems that the addition of ECC technology could affect:

- Boiler exhaust (including composite boiler).
- Auxiliary diesel engine exhaust.
- Main diesel engine exhaust.
- Boiler relief valve vents.
- Inert gas generator combustion exhaust.
- Inert gas generator excess air outlets.
- Incinerator exhaust.
- Various vents.

While not an exhaustive list, the subsequent sections outline several key areas of concern. Addressing these concerns is vital when considering the adoption of ECC technology on tankers.

7.1 Potential operational disruption to tanker machinery due to ECC technology

Examples of potential operational disruption include the following:

- Boilers: poor combustion or complete shutdown, potentially overheating the boiler or causing an explosion.
- Main or auxiliary diesel engine: poor combustion or complete shutdown.
- Inert Gas System (IGS): backpressure or pressure fluctuations affecting the ability of the IGS to manage the oxygen content of the inert gas. This could result in an unacceptable oxygen content in the inert gas supplied to the cargo block or the shutdown of the inert gas equipment. Failure to maintain prescribed oxygen content levels in the IGS would necessitate the shutdown of cargo operations.

7.2 Potential for introduction of exhaust gas in the accommodation block (manned spaces) due to collector covering multiple stacks

When the collector covers multiple stack openings, exhaust gas can potentially be introduced into the accommodation block through the adjacent stacks of offline equipment (diesel engines, boilers, incinerators). This can present safety and health risks for crew members and lead to the contamination of ship systems, such as the lube oil sumps of the main and auxiliary engines.

7.3 High quantity of unburnt fuel in the exhaust stream affecting ECC equipment

Boiler Combustion Control (BCC) systems are designed to minimise the presence of unburnt fuel in the exhaust stream or fuel accumulations in the firebox. A flame failure or multiple failures to ignite can lead to fuel accumulation in the firebox, resulting in a fuel-rich atmosphere. Following this type of event, the BCC system is designed to initiate a purging process before re-ignition.

This critical procedure involves clearing the firebox of flammable mixtures with air, thereby expelling the fuel-rich atmosphere out of the stack. The expelled fuel-rich mixture would then be introduced into the heater within the ECC treatment system, potentially creating a risk of explosion.

Fouled burners in a boiler or fouled injectors in a diesel engine can also lead to the presence of unburnt fuel in the exhaust stream, which presents additional risks to the safe operation of an ECC system.

7.4 Pressure surges at the collector inlet

Pressure surges at the tanker's funnel, caused by events such as boiler ignition, the starting of an inert gas generator or the release of a boiler safety valve, can create challenges when an ECC collector covers the stack/funnel. These surges can lead to abrupt increases in pressure, potentially affecting the operation of the ECC technology, overwhelming the capture system's capacity, causing backpressure issues to the vessel equipment, or impacting on the safe positioning of the collector.

8 Risks associated with hazardous substances on ECC barge

Hazardous substances, such as ammonia solution, may be used onboard the ECC barge as part of the normal operation of the exhaust gas treatment system. Other hazardous substances, such as hydrocarbons, may reach the barge due to abnormalities in the tanker or terminal. Those substances can be flammable, toxic to humans, or cause an oxygen-depleted atmosphere, potentially being significant threats to operating personnel in case of loss of containment. The present section addresses the safety measures that should be implemented to reduce the risks posed by such hazardous substances, which include accumulation of flammable or toxic gas concentrations and asphyxiation.

8.1 Potential sources of hazardous substances

The following are potential origins of the risks associated with the presence of hazardous substances on the barge:

- Loss of ammonia solution containment from the exhaust gas treatment system: anhydrous ammonia, aqueous ammonia, urea-based ammonia, or other substances may be used onboard the ECC barge to treat the tanker's exhaust gas. Depending on the barge's design, the ammonia solution could be contained in an enclosed space or an area open to the atmosphere. A leak associated with the ammonia solution storage, transportation, or operating system could release ammonia solution into the atmosphere, thus creating a hazardous environment.
- Loss of exhaust gas containment from the exhaust treatment system: a leak in the ductwork could release exhaust gas into the atmosphere, which may contain unburnt hydrocarbons, CO, CO_2, SOx, NOx, and particulate matter.
- Loss of containment of fuel used in the ECC treatment process: methane and propane are examples of fuels that may be used in the exhaust gas treatment system. A fuel storage or supply system leak could create a hazardous atmosphere.
- Toxic risk, including H_2S, from the tanker's cargo and potential residual fuel in the exhaust stream: the tanker's residual fuel oils may contain H_2S, which could be released into the atmosphere. Additionally, tankers may carry cargo containing H_2S, which could be released into the atmosphere during cargo operations.
- Loss of containment of fuel used in the ECC barge propulsion system: a loss in containment of the barge fuel during operation or bunkering can pose a risk to the crew. Additionally, the ECC barge may use alternative fuel to reduce its harmful air emissions. Some of those fuels can have low flashpoints, be more toxic and more volatile than diesel.

- Hazardous conditions resulting from improper storage of hazardous products: lubricants, paint and other hazardous products may be stored in the ECC barge. A loss of containment or improper storage of those products could generate a hazardous atmosphere.

8.2 Gas measurement

ECC barge operators should consider installing fixed gas detection, oxygen measurement, and alarm equipment in areas where personnel may be exposed to hydrocarbon gases, other toxic gases, and low oxygen levels, as identified by a risk assessment.

Fixed gas detection systems are typically permanent, electrically operated devices that sense the presence of combustible or toxic gases and provide early warning before the gas concentration reaches the flammable range or acute or chronic toxic levels. They continuously monitor potentially hazardous areas to safeguard against fire or explosion and to protect personnel from toxic gas leaks.

Oxygen sensors continuously monitor the concentration of oxygen in the atmosphere. They provide early warning when oxygen levels fall below the safe limit for human respiration, safeguarding against oxygen deficiency and potential asphyxiation. These sensors are crucial for monitoring enclosed spaces and other areas where oxygen depletion could occur, ensuring a safe working environment for personnel.

Fixed gas detection and oxygen measurement should be installed where this risk to personnel exists as identified by a risk assessment, which should consider the following:

- The overall safety and health risk to personnel from hydrocarbon and toxic vapours.
- The appropriate placing of sensors in locations where personnel may work and where leaks or spills could occur to ensure that early and adequate warning of an increased risk of exposure is provided.
- Whether the area is adequately ventilated to minimise or eliminate the potential for gas to accumulate.

Toxic gas detectors may also be installed in the supply air intakes of pressurised control rooms and inside non-pressurised control rooms. If, after the risk assessment, there remains doubt that exposure to personnel could occur, the fitting of fixed gas detection is recommended.

In addition to fixed sensors, ECC operating personnel should always consider carrying portable sensors.

The ECC operator should document and be able to demonstrate that any measurement instrument used is:

- Suitable for gases and atmosphere to be tested.
- Sufficiently accurate for the test required.
- Used within instrument design ambient range.
- An approved type.
- Correctly maintained, tested and calibrated.

The operating principles and limitations of equipment and instruments used for measuring concentrations of hydrocarbon gases, other toxic gases, and oxygen can be found in the *International Safety Guide for Oil Tankers and Terminals (ISGOTT).*

8.3 Control of potential ignition sources

Naked lights and smoking should be prohibited on the ECC barge deck and other areas where flammable gas may be present. Suitable notices should be clearly displayed marking these zones, and all personnel, including visitors, should be made aware of these restrictions.

Smoking presents significant safety risks. Controls should be established through the barge SMS requirements and design, e.g. dedicated smoking compartments. Controls for smoking should also be applied to any other products that are burned. Any smouldering, smoke-producing product should never be left unattended or allowed near bedding or other combustible materials. Suitable notices of the designated smoking places should be clearly displayed, and ECC barge personnel should know where they are.

Electronic devices, such as mobile phones, laptops, cameras and other portable electronic equipment, should be strictly controlled in hazardous areas. Sparks from batteries, electrical components or radio frequency emissions can cause ignition.

Only intrinsically safe electronic devices, certified for use in the specific hazardous area classification, should be permitted.

Where possible, designate specific areas on the barge where non-intrinsically safe electronic devices can be safely used. These areas should be clearly marked and located away from hazardous zones.

Barge personnel should comply with *ISGOTT's* relevant requirements, particularly restrictions on smoking, naked lights and cooking appliances. Additional precautions should be taken to control other potential ignition sources, such as:

- Static electricity: measures should be taken to prevent the build-up and discharge of static electricity, especially when handling flammable liquids or gases. This could include bonding and grounding equipment, using anti-static materials and controlling flow rates.
- Machinery and equipment: all machinery and equipment should be adequately maintained and inspected to prevent sparks or overheating.

Hot work and maintenance activities, such as welding, cutting and grinding, should be strictly forbidden when operating with a tanker.

9 ECC Safety Management

A Safety Management System (SMS) is a formal, documented system or framework designed to manage safety in the workplace. It includes policies, objectives, plans and procedures, and organisational responsibilities for those involved in ensuring the system is effectively implemented.

The ECC operator should have an SMS involving policies, procedures and practices that facilitate identifying, assessing, and controlling risks and promote a safety culture. The SMS should cover all aspects of the ECC operation, including managing interfaces with the tanker and the terminal.

Toolbox talks are an important part of any SMS. A toolbox talk is a short, informal safety meeting typically held at the worksite before the start of a task. It provides an opportunity for workers to discuss the hazards of the task, the control measures that will be used and any specific safety concerns.

ECC operators should implement toolbox talks to allow the barge crew to discuss and address specific operational topics, share best practices, and enhance their understanding of safety procedures and protocols. Regular toolbox talks can help promote a culture of continuous improvement, teamwork, and adherence to operational standards.

For further SMS and toolbox talks guidance, refer to *ISGOTT.*

10 Competency and training of ECC personnel

This section provides guidance for the competency and training of ECC personnel.

The workers handling the tasks on the ECC barge should be trained and competent. They should possess and be able to demonstrate competencies associated with the following circumstances:

- All operations on the ECC barge, including emergencies.
- Hazards related to operating in oil terminals and the vicinity of tankers carrying dangerous cargo.
- Manoeuvring the barge, station keeping, remote deployment of the collector on multiple stacks, risks and mitigations related to tanker and barge interface.

- Tanker and terminal emergencies like oil/gas spills, fires, machinery failures, etc.
- Communication protocols, adherence to standard operating procedures (SOPs), understanding of human factors, etc.
- Tanker and terminal security protocols.

Operator training and competency should be based on and include the following:

- Minimum operator competency requirements.
- Training on barge-specific equipment, including ECC capture system, treatment system, process control system, manoeuvring, mooring and station-keeping, etc.
- Familiarity with risks and hazards associated with operating ECC barges in oil terminals and adjacent to tankers. Consideration should be given to training related to dangerous cargo.
- Periodic drills to continually improve and grow operator competency in normal and emergency scenarios.
- A competency matrix to document each operator's training, drills, and competencies, identify gaps, and build a robust competency management process.
- Usage and location of Personal Protective Equipment (PPE) and safety equipment.

ECC operators should be provided with written guidance and instructions to ensure the safe, consistent, reliable, and efficient performance of their functions. Approved SOPs and processes should be established for all normal and emergency operations. Continuous and demonstrable efforts should be made to improve and update these SOPs and processes.

10.1 Management of SIMOPS

Introducing an ECC barge alongside a tanker at berth creates an additional hazard that needs to be safely managed. While the ECC barge operates with the tanker during a cargo transfer operation, the tanker should be considered as undertaking a simultaneous operation (SIMOP).

The guidance contained in *ISGOTT* regarding the management of SIMOPS should be applied.

ISGOTT recommends that SIMOPS are identified early and that a risk assessment is conducted to identify the hazards of each operation and the risks from their interaction. The risk assessment should consider factors such as schedule and workload clashes, resource availability, and the need for supervision. Based on the risk assessment, a SIMOPS plan should be prepared that outlines the planned controls to ensure the operation is managed effectively and risks are reduced to an acceptable level. Toolbox talks should then be used to review the SIMOPS plan, and these should include discussion on the implementation of the control measures and any potential conflicts or challenges.

To reduce risk, the ECC barge should be designed and operated to minimise the need for other SIMOPS during the capture and control operation. When in operation, the ECC barge should avoid maintenance, repairs, hot work, bunkering, reception of supplies, and other simultaneous activities.

11 Manning requirements

The ECC barge operator should establish a minimum safe manning level considering the recommendations contained in this section.

11.1 General recommendations for manning

Staffing will depend on the needs of the barge operations. Therefore, it is recommended that staffing plans be reviewed using the human factors approach, considering operational and security requirements, including emergencies. A risk assessment should be completed to determine appropriate staffing levels.

ECC barge operators should refer to IMO Resolution A1047(27) Principles of Minimum Safe Manning and Flag State requirements and consider the unique site-specific requirements of the

ECC operations to determine and produce the Minimum Safe Manning Document (MSMD). This document should be shared with the terminal and tanker before operations.

The following recommendations should be considered when developing the MSMD:

- General operation:
  - It is generally understood that the operation of ECC technology will require sufficient personnel, including, but not limited to, collector deployment and retraction and position management, process efficiency, control system and alarms, communication, barge position relative to the tanker, managing fatigue, and crew change.
- Barge towing or propulsion:
  - Sufficient competent personnel are always available onboard the barge to perform all actions associated with emergency disconnection, unmooring, and manoeuvring.
- Station-keeping and spud placement/removal:
  - It is expected that barge placement relative to the tanker and associated mooring equipment may require additional personnel to support the deployment of spuds while providing sufficient personnel for emergency support.
- Capture technology placement and removal.
- Emergency response:
  - Each emergency response plan must consider minimum manning for each scenario.

12 Human factors

This section describes the risks associated with human factors.

12.1 Background on human factors

Human factors are the characteristics that affect human interaction with equipment, processes, and other people. They can include physical, psychological and social factors. Humans contribute to most incidents, and wherever people are involved in the design, construction, or operation of equipment and processes, human error is likely.

Human error, actions and decisions are often the result of how the workplace is set up, i.e. how work, equipment, and safeguards are designed and how leaders influence an organisation's culture.

Incidents start as mistakes or workarounds that stem from the following circumstances:

- Problems with tasks.
- Unclear procedures.
- Difficult to use equipment.
- Workload fatigue.
- Lack of resources.
- Low quality or insufficient training.
- Improper communication.
- Improper situational awareness.

Tackling underlying conditions and hard-to-use systems that influence human error, actions, and decisions can reduce the likelihood of incidents. People in leadership play an essential role in this. The human factors and influences are summarised in the following principles:

- People will make mistakes.
- People's actions are rarely malicious and usually make sense to them at the time.
- Mistakes may be due to conditions and systems that make work difficult.
- Understanding the conditions under which mistakes happen helps to prevent or correct them.
- People know the most about their work and play a critical role in identifying solutions.

- Facilities, equipment and activities can be designed to reduce mistakes and manage risk better.
- People in charge of activities help shape the conditions that influence what other people do.
- It matters how those in charge respond when things go wrong and that they take the opportunity to learn.

12.2 Hierarchy of controls

The hierarchy of controls provides a recommended order of priority for selecting preventive and mitigating measures or controls to reduce risk to a level that is As Low As Reasonably Practicable (ALARP).

The hierarchy of controls is as follows:

1. Elimination: remove the cause of the hazard completely, e.g. by not performing a proposed operation.
2. Substitution: replace the proposed procedure with a less hazardous one.
3. Engineering controls: physically separate personnel from hazards, e.g. fitting guards at dangerous equipment, rigging barriers around open hatchways, or using Lock-out/Tag-out (LO/TO) equipment.
4. Administrative controls: use procedures to perform tasks safely, e.g. hot work permits, enclosed space entry permits, hazard identification tools, risk assessments and duty rosters to minimise exposure to hazards.
5. PPE: use PPE to protect the person carrying out the operation, e.g. safety glasses. Select PPE to mitigate against the identified hazard. Train personnel on how to use it correctly, including how to check if it still fits the intended purpose.

This hierarchy of controls recognises that eliminating a task may provide the best protection against the risk from that task, especially when compared to the less effective controls of additional procedures or signage. It also recognises that humans make mistakes and that relying on people to always follow procedures or wear PPE correctly is not always effective.

As you move down the hierarchy of controls, the level of supervision required to ensure the control's effectiveness increases. Elimination and substitution, the most effective controls, require the least supervision. Engineering controls require regular inspection and maintenance. Administrative controls require active supervision to ensure procedures are followed. PPE, the least effective control, requires constant supervision to ensure it is worn and used correctly.

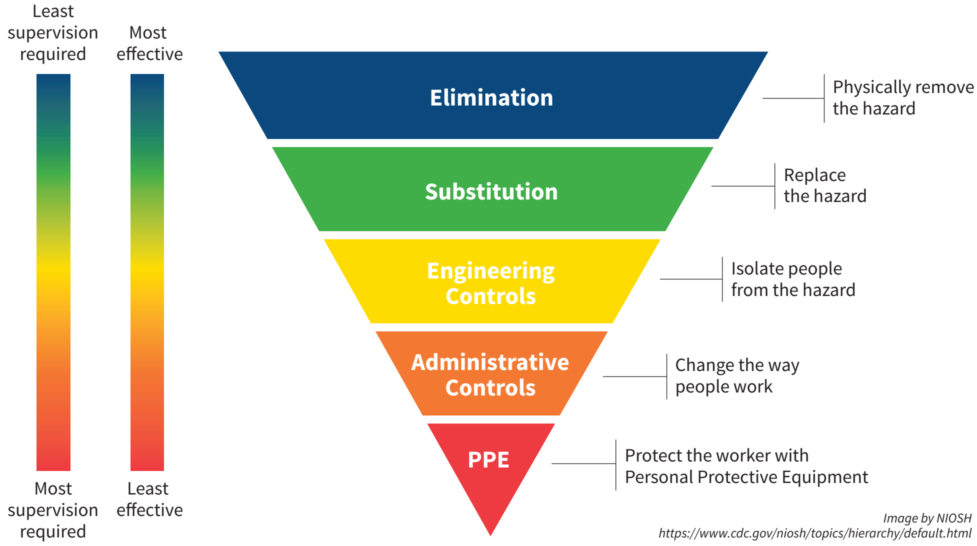


Figure 12.1: *Recommended hierarchy of controls*

12.3 Potential hazards associated with human factors

This section describes potential hazards associated with human factors, which include the following:

- Human error.
- Personnel exposure to adverse conditions (high temp surfaces, low oxygen, harmful emissions, or electrocution risk).
- A person in the water.
- Personnel injury due to dropped object or human position during lifting operation.
- Slips, trips and falls, including from height.
- Collision with marine traffic while underway.
- Allision with a moored tanker or terminal structure.
- Structural or equipment failure or damage on barge or tanker.
- Incorrect deployment, positioning and retracting of ECC boom and collector.
- Failure to egress from the moored location during an emergency on the ECC, tanker or terminal.

12.4 Preventive measures for human factor-related risks

This section lists preventive measures for human factor-related hazards to be adopted in operations involving ECC:

- Development of a Safety Management System (see section 9).
- Establishment of safety barriers following the recommended hierarchy of controls (section 12.2) to reduce risk to ALARP.
- Identification of process safety-critical equipment (see section 13) and inclusion of redundancies in equipment design (see section 14).
- Maintenance and integrity programme.
- Design of capture technology that does not require ECC personnel on board the tanker.
- Minimisation of personnel transfer from and to the ECC barge and the use of appropriate support craft for such transfers.
- ECC barge design to include:
  - Handrails on barge working surfaces.
  - Dedicated ladder or stairs to transfer personnel on/off the barge.
  - Personal gas detection and oxygen sensors.
  - Engineering safeguards.
- Towing vessel assurance process.
- Procedures, staffing, fatigue management plan, training and pre-ops checklists.
- Avoiding SIMOPS for ECC barge (see section 10.1).
- Avoiding tanker bunkering operation simultaneous with ECC operation.
- Managing the risk from other tanker SIMOPS to the ECC barge. Examples include:
  - Tanker mooring/adjustment.
  - Tanker receiving provisions.
- Restricted access to the deck area near the ECC boom and collector during deployment and retraction.
- PPE.
- Establishing a communication protocol and operational plan for barge/tanker/terminal interface.

12.5 Mitigations and response planning

This section lists mitigation measures for human factor-related hazards to be adopted in operations involving ECC:

- Life-Saving Appliances (LSA):
  - Lifeboat/raft, life rings, throwing lifeline, emergency escape breathing device, defibrillator, first aid equipment, etc.
- Fire Fighting Appliances (FFA):
  - Fire detection systems, fire extinguishers, fixed systems (as required), etc.
- Emergency Response Plan/procedures:
  - Fire/explosion.
  - Pollution/vapour release.
  - Collision/allision.
  - Structural/equipment failure.
  - Medical/first aid event.
  - Fall from height/fall to water.
  - Emergency Shut Down/evacuation/departure.
  - Internal emergency – system process event.
  - External emergency (tanker and terminal).
  - Environmental emergency.
- Training/drills.
- PPE.

13 Process safety-critical equipment

Process Safety-Critical Equipment (PSCE) encompasses equipment, control systems or protection devices whose failure could directly lead to an accident involving a release of hazardous substances, fire or explosion. These failures can stem from various sources, including equipment malfunction, human error, external factors, or a combination thereof.

Identifying PSCE is a crucial step in managing process safety risks. This identification should be conducted through a risk assessment, as outlined in *ISGOTT.* The risk assessment should consider the following factors:

- Potential consequences of equipment failure: what are the worst-case scenarios if this equipment fails? Consider the potential for harm to people, the environment, and assets.
- Likelihood of failure: how likely is this equipment to fail based on its design, age, maintenance history, operating conditions and other relevant factors?
- Safeguards in place: what existing safeguards prevent or mitigate the consequences of equipment failure? This includes inherent design features, operational procedures and safety systems.

Once PSCE is identified, special considerations should be applied to its management, including:

- Prioritised inspection, testing, and maintenance: PSCE should be given priority over other equipment in the Planned Maintenance System (PMS). This includes more frequent inspections, testing, and preventive maintenance.
- Redundancy and segregation: where possible, redundancy should be incorporated into the design of PSCE to minimise the effect of a single-point failure. Additionally, the segregation of PSCE from other equipment and potential ignition sources should be considered to prevent cascading failures. See section 14 for further details.
- Competent personnel: only personnel with the necessary training, experience, and qualifications should be authorised to operate, maintain and repair PSCE.

- Safety critical spare parts: an adequate inventory of safety-critical spare parts should be readily available to ensure timely repairs of PSCE. This inventory should be determined based on risk assessment and reliability analysis. Factors such as the likelihood of failure, procurement lead times, and the importance of the equipment should be considered to maintain the right stock of spare parts, consumables and tools onboard, minimising potential downtime.
- Emergency response: emergency response procedures should be developed and practised for scenarios involving the failure of PSCE. This includes methods for isolating the equipment, containing any releases and evacuating personnel.
- Continuous monitoring: where appropriate, continuous monitoring systems should be installed to detect potential PSCE failures. This could include gas detectors, pressure sensors, temperature sensors and other relevant monitoring devices.
- Management of change: any modifications to PSCE or its operating procedures should be carefully managed through formal management of change process to ensure that safety standards are not compromised.

Refer to the OCIMF publication *Safety Critical Equipment and Spare Parts Guidance* for additional considerations related to spare parts to PSCE, which include:

- Enabling materials: in addition to spare parts, ensure the availability of all necessary enabling materials, such as tools, drawings, manuals and consumables, to facilitate timely repairs of PSCE.
- Temporary repairs: temporary repairs may be needed in abnormal situations but should not be treated as a permanent solution. Operational controls may be required during this period, and permanent repairs should be completed as soon as it is safely possible. The ECC operator should ensure that any necessary repairs on the barge can be made without compromising the tanker's ability to disconnect and leave the berth within the regulatory maximum time.
- Vendor support: for complex or proprietary equipment, vendor support may be required for diagnosis, repair and provision of spare parts. This should be considered in the overall maintenance strategy.

The ECC operator should establish, document and share the maintenance and repair philosophy and plans with the terminal and tanker. If maintenance is to be carried out by the ECC personnel, adequate operator competencies should be included in the training and competency programme (see section 10). If a third party performs all maintenance and repair activity, the ECC operator should provide details of such arrangements and include procedures for routine and emergency repairs to ensure reliable and safe operations.

14 Redundancy and secondary means of operations of ECC equipment

The ECC barge reliability and blackout response should be considered to mitigate effects from equipment failures or primary power loss onboard.

A failure modes and effects analysis should be conducted to identify the various modes of operations and methods of prevention and mitigation of power failure or loss of operational control for each mode.

The ECC operator should identify critical systems for process safety. Secondary means of operating those systems should be provided in case primary electric and hydraulic power are lost. Those systems may include the following:

- Fire suppression systems.
- Emergency ventilation.
- Hazardous gas monitoring system.
- Emergency lighting.
- Systems to lift the collector clear of the tanker's funnel.

- Spud lifting system and or mooring winches and lines.
- Manoeuvring systems.
- ECC collector position monitoring.
- Exhaust gas treatment system.

Operations to be evaluated should include the following:

- Keeping the collector in position during the capture of exhaust gases.
- Managing a failure of the lifting gear (boom) while deploying, positioning or retracting the collector on the tanker.
- Assessing the effect of gas processing equipment failure on tanker equipment.
- Ensuring the ability to retract the spuds in an emergency, even if the ECC barge loses its primary power source.
- Shutting down all non-intrinsically safe equipment on the ECC during a potential flammable product release on the tanker or terminal.
- Using LSA and fire-fighting equipment, including fire suppression systems, on the ECC barge in response to a release of hazardous substances on either the tanker or the ECC barge.

Due to the risk of the collector falling onto the top of the stack, rigidly entangling the two vessels, a fail-up mode should be considered for the boom.

Periodic inspection and planned maintenance schedules should be developed and adhered to to ensure the reliability of safety-critical and other systems.

Generators, switchboards, fuel tanks, fuel supply systems, fans, Hydraulic Power Pack Units (HPPUs), heat exchangers, pumps, SCRs, chemical dosing systems, pressure sensors, temperature sensors, Continuous Emission Monitoring System (CEMS), etc should be installed in 2 x 100% or 3 x 50% configurations to eliminate single points of failure.

Marine electrical best practices should be applied, including power management systems and monitoring.

Blackout recovery procedures should be developed, and drills should be conducted to assess the readiness and effectiveness of backup systems.

15 Barge design and construction verification

It has been recognised that prescribed design and construction standards, such as those developed by the US Coast Guard or existing classification society rules, do not specifically address ECC barges operating in port areas. The ECC barge's design, construction, and operation are recommended to be approved against classification societies' rules and guidelines. Although specific regulations for these barges may not yet exist, classification societies provide a framework for ensuring that all aspects of barge design meet adequate engineering standards.

The following key aspects underline why design verification remains essential for these vessels:

- Stability (intact and damaged): ensuring that ECC barges possess both intact and damaged stability is critical to their safe operation. Verification ensures that the barge can remain upright and stable during normal operations and after sustaining damage, such as a collision or flooding incident. This is crucial to prevent capsizing and maintain the barge's operational integrity in emergencies.
- Structural integrity: ensuring that ECC barges can withstand the dynamic forces encountered in port environments, including those from metocean conditions. Design verification ensures that the barge's structure is robust enough to endure these stresses without compromising safety. Special attention should be given to the structural integrity of the boom, ductwork and exhaust gas collector.

- Safety of machinery and systems: the machinery and systems on ECC barges, including those for position keeping and those used for lifting the collector, exhaust gas treatment and emissions capture, should be designed to operate safely and reliably. Verifying these systems ensures they meet safety standards, reducing the risk of mechanical failure, fire, or other incidents. This includes assessing emergency systems, such as fire detection, monitoring and suppression, and emergency power, to guarantee they function as required during abnormal events.
- Appropriate materials and construction: verification ensures that suitable materials are selected, considering fire resistance and structural strength factors. Proper construction practices, including quality control during fabrication, should also be checked.
- Fire safety plan and life-saving appliances: verification ensures that the fire safety plan developed for both the barge and the exhaust treatment system is comprehensive, covering all elements to safeguard the barge and the crew in an emergency. Considering the barge's operational profile, the plan should also cover the dedicated life-saving appliances.

16 Communication protocols

The following guidance outlines the communication protocols to be established and maintained between the ECC barge, the tanker, the terminal and other relevant parties:

- Communication equipment:
  - Primary system: establish a dedicated communication channel between the ECC barge, the tanker and the terminal, ensuring personnel continuously monitor it.
  - Secondary system: implement a secondary, independent communication system separate from the primary one. This system should be tested regularly to ensure it is operational. Options may include a VHF/UHF radio system or a dedicated telephone line, including the availability of intrinsically safe equipment.
  - Emergency signals: pre-agree on emergency signals that are distinct from routine communications. All parties involved – ECC barge, tanker and terminal – should clearly understand these signals which should unambiguously indicate the need for immediate action.
- Communication procedures:
  - Language: English should be the standard for all verbal communication between the ECC barge and the tanker. If language barriers exist, appoint a person with sufficient technical and operational knowledge and proficiency in a common language to facilitate communication.
  - Clarity and conciseness: to prevent misunderstandings, ensure all communication is clear, concise and unambiguous. Use standard marine communication phrases outlined in IMO Standard Marine Communication Phrases, Resolution A.918(22), where applicable.
  - Pre-arrival communication: all parties need to communicate before the tanker arrives. This should include sharing information to ensure the ECC system, tanker and terminal are compatible. For example, the tanker should inform the ECC operators about the conditions and arrangement of its funnel and stacks. Tanker and terminal hazardous areas should also be informed to the ECC barge as part of such communication.
  - Pre-operation conference: conduct a pre-operation conference between the ECC barge operator and the tanker's Responsible Officer before starting operations. This conference should comprehensively cover communication procedures, emergency signals and any specific operational requirements or limitations.
  - Regular communication checks: perform regular checks of the primary and secondary communication systems throughout the operation. Any failure to respond should be promptly addressed as a potential emergency.

- Emergency communication:
  - Raising the alarm: in an emergency, the ECC barge operator should immediately raise the alarm using the pre-agreed emergency signals and contact the tanker, terminal and other relevant parties via primary and secondary communication systems.
  - Information to be relayed: emergency communication should be clear and concise, detailing the nature of the emergency, its location, actions being taken and the assistance required.
  - Maintaining communication: continuous communication with the tanker, terminal and relevant parties throughout the emergency response is essential to ensure coordinated action.
  - Designated spokesperson: appoint a single spokesperson on the ECC barge to manage all external communications during an emergency. The designated spokesperson should be identified and documented in the ECC barge's SMS and be competent in the agreed communication systems and protocols.
- Compliance with terminal and local regulations:
  - The ECC barge operator must comply with all terminal and local regulations concerning communication procedures and emergency signals. It is essential to be familiar with these regulations before the tanker arrives and adhere to them throughout the operation.

Radio and other communication equipment used during routine and emergency scenarios should comply with the intrinsic safety requirements outlined in section 8.3. Please refer to *ISGOTT* for more details on the definition of adequate communication protocols.

17 Emergency protocols

Emergency protocols are essential to respond to potential incidents while operating with an ECC barge. These protocols should be developed based on a risk assessment, and the emergency response plan should be well-documented, regularly reviewed and updated, and practised through drills.

Those protocols should address, but not be limited to, the following:

- Emergency shutdown and retraction of the ECC boom.
- Barge emergency departure, including spuds retrieval if applicable.
- Loss of station keeping, including mooring and spud failure.
- Firefighting.
- Use of emergency escape breathing devices in the case of toxic atmospheres.
- Crew evacuation.
- Medical emergencies.

18 Next steps

An OCIMF guide covering additional aspects of the safe application of ECC to tankers, including the management of interfaces, will follow this paper. Topics to be considered in the future guide may include the following:

- Additional engineering and operations safeguards not addressed within this document.
- Details on aspects of the ECC technology not covered within this document.
- Ship/shore/barge pre-operational checklist.
- Compatibility checklist.
- Other implications of the ECC barge to the port's manoeuvring area.
- Marine assurance processes for the ECC barges.

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