TECHNICAL SEMINAR on Onboard
Carbon Capture and Storage(OCCS) Systems

Developing Total Solutions for OCCS

Insights from "Real-Ship Projects" in Safety, Operation, and Regulation

PRESENTED BY KR KOREAN REGISTER PANASIA

September 11th, 2025

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Chapter

Introduction

- Why OCCS, its Opportunities and Challenges

Why OCCS, its Opportunities and Challenges

OCCS is an immediate solution to achieve Net Zero by 2050

1. To adopt OCCS to vessels to meet Net Zero by 2050, especially for existing fleets is inevitable
2. However, in the process of applying it to actual ships, there are various technical, operational, and regulatory hurdles.

Safety

- Large CO_2 storage in non-gas carrier
- Amine
- Refrigerant

Training

- Unfamiliar to seafarers
- Assistance from shore-based experts is required.

Value chain

- No experience for unloading and utilization.

Efficiency

- Energy is consumed during carbon capture and liquefaction.

Space

- Equipment consumes space and adds weight, resulting in a reduction of cargo capacity.

02

Chapter

Real-Ship Application Overview

- Brief on real-ship demonstration consortium
  : Korean Register, PANASIA, Samsung Heavy Industries, HMM
- Vessel Information
- OCCS Flow Diagram & Specification

Brief on real-ship demonstration consortium

Consortium for Onboard Carbon Capture System

Teaming up to reduce the GHG in short term

KOREAN REGISTER

Classification

Survey & Research

- Drawing approval
- Risk assessment
- Safety rule development

Container Ship Operation

- Ship owner
- Captured CO_2 unloading

HMM

Ship Owner

PANASIA

Equipment Maker

OCCS Supplier & Retrofit

- Carbon capture system supplier
- Retrofit engineering

Liquefaction Facility

- Liquefaction system supplier
- Captured CO_2 utilizing

SAMSUNG

Ship Builder

Vessel Information

Fundamental Design check-up points

SHIP'S PARTICULAR

Vessel Name / Flag	HMM MONGLA / JEJU, KOREA
Vessel Type	Container Vessel
Vessel Capacity	2,200 TEU
Fuel Type	HFO (With SOx-Scrubber)
1-Cycle Voyage Period	270 days voyage/year
Fuel Consumption	29.7ton per day
Vessel CO_2 Emission Per Year	24,977 Ton.CO_2/year

Item	Spec.
Electrical power	6650 kW
Composite boiler	1.6t(Exh.) / 1.8t(O.F)
F.W Gen.	25 t/day

OCCS Flow Diagram & Specification

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1 Pre-treatment of Flue Gas

Flue gas is cooled, and particles and sulfur oxides are removed. It is then pressurized and sent to the absorber.

2 CO_2 Absorption

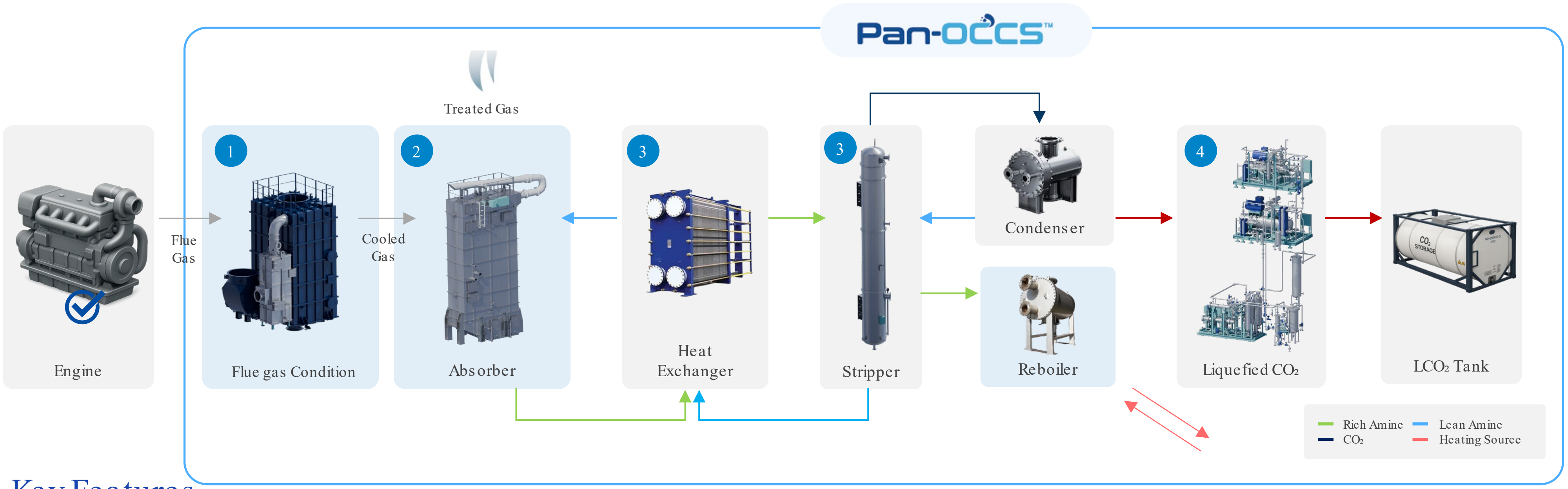
The cooled gas contacts a chemical solvent in the absorber, selectively capturing CO_2.

3 Regeneration

The solvent is heated by a reboiler to release the captured CO_2 and regenerate it for reuse.

4 Liquefaction & Storage

CO_2 is liquefied through compression and cooling, allowing safe marine storage and efficient onshore off-loading.



OCCS Specification

Items	Value
Feed Flue gas volume	14,000Nm³/h
Capture level	90%
Captured CO_2	1,039kg/h
Product LCO_2	1,018kg.LCO_2/h
Purity of product LCO_2	99.9%
Solvent flowrate	11.3ton/h
Additional fuel for OCCS	123kg/h
Waste heat usage	15% of heat energy
Captured CO_2	6,596ton/year

Key Features

- Combined functions of Scrubber and OCCS
- Optimized Space utilization
- Improved energy efficiency

03

Chapter

Design Optimization and Efficiency Considerations

- Feasibility Study
- Technical Challenges
  - OCCS Optimization – Space & Energy
  - LCO_2 storage design
  - Supporting Crews
- Voyage Summary of HMM MONGLA during Past 1 Year
- Offloading LCO_2

Feasibility Study 1 Successfully Completed

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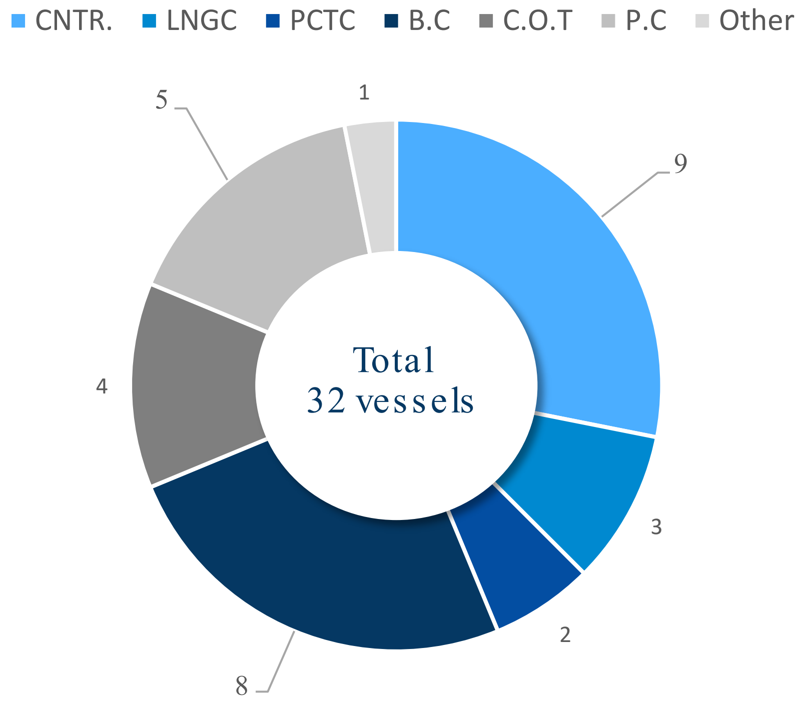
The system has been applied to various vessel types, including bulk carriers, tankers, and gas carriers, with supported capacities ranging from 0.5 to 8 tons per hour.



1. Technical Challenges I OCCS Optimization – Space & Energy

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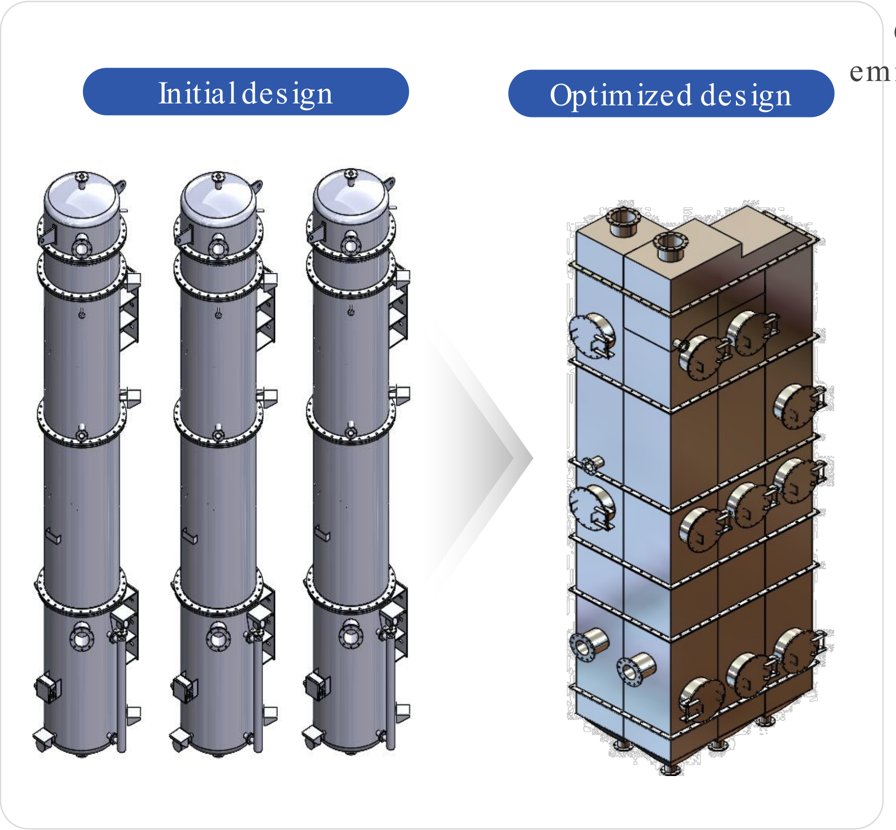
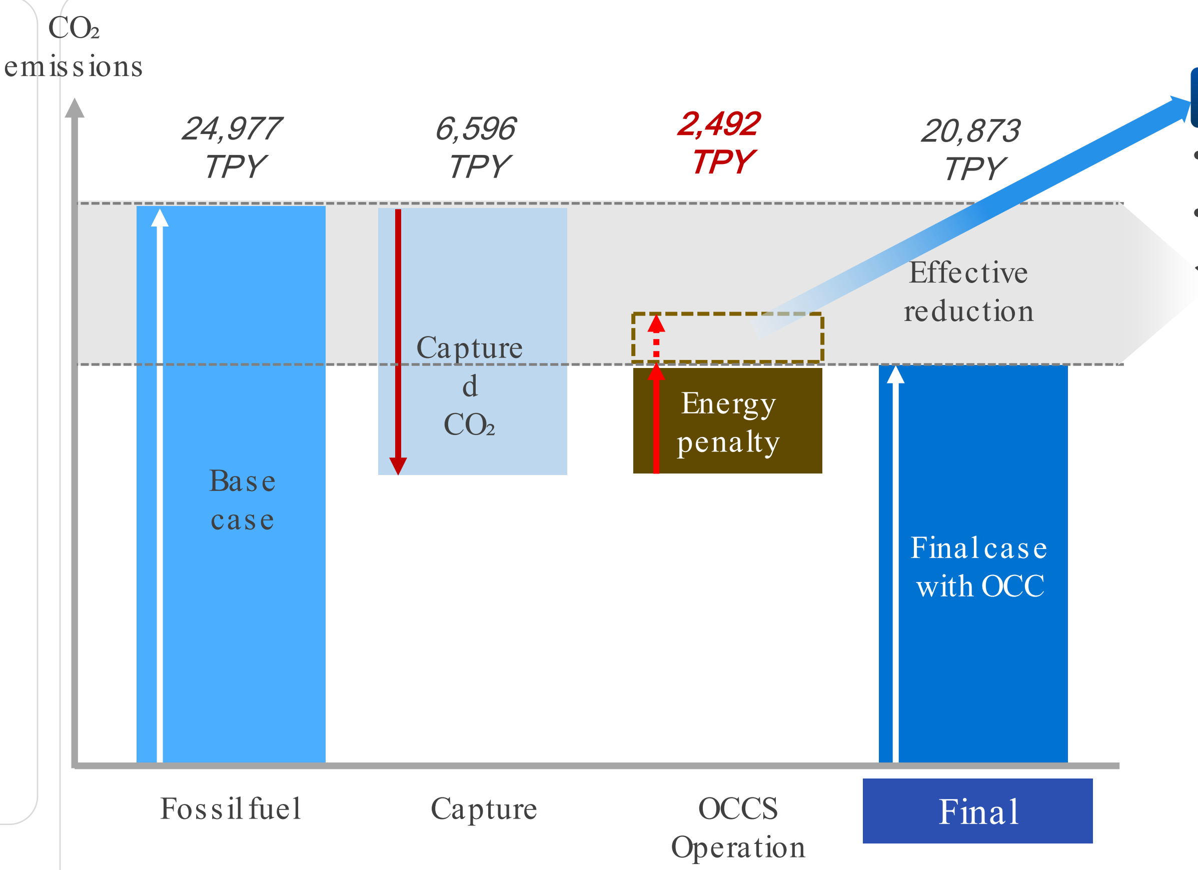
Adding OCCS into optimized designed vessel is a challenge.
However, one tower solution and Reboiler for Amine delivers a Optimized solution in efficiency





For Reduce Energy Penalty

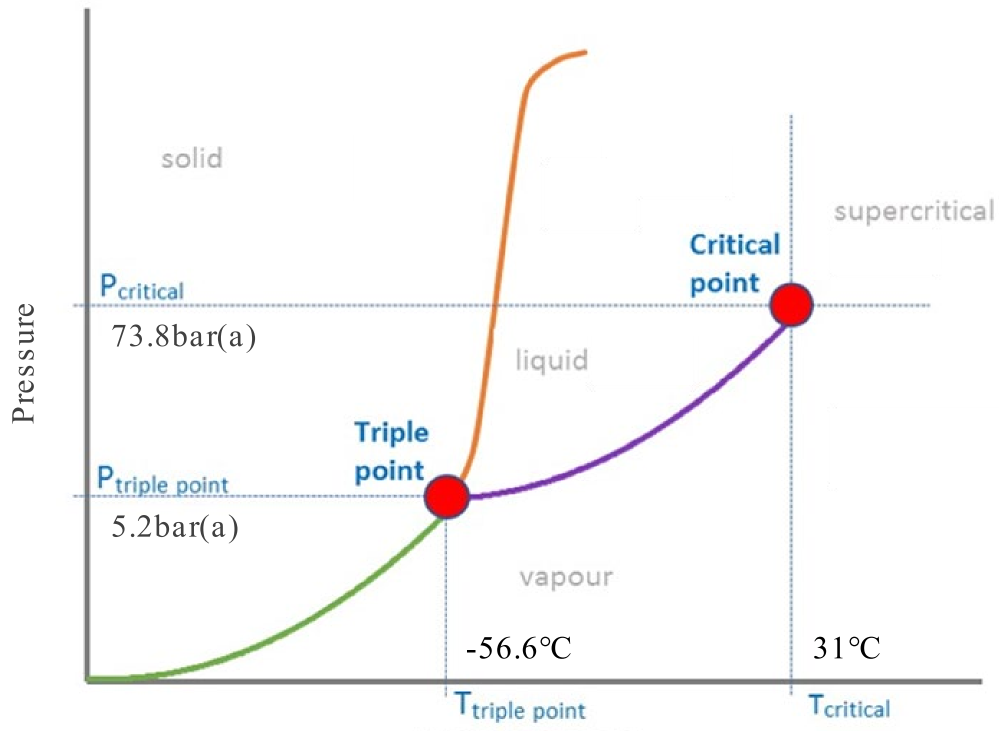
- Waste heat for amine heating
- Low energy for amine solvent
- High efficiency heat exchanger

Amine economizer

2. Technical Challenges I LCO_2 storage design

Design of LCO_2 Storage is various and requires the common standard

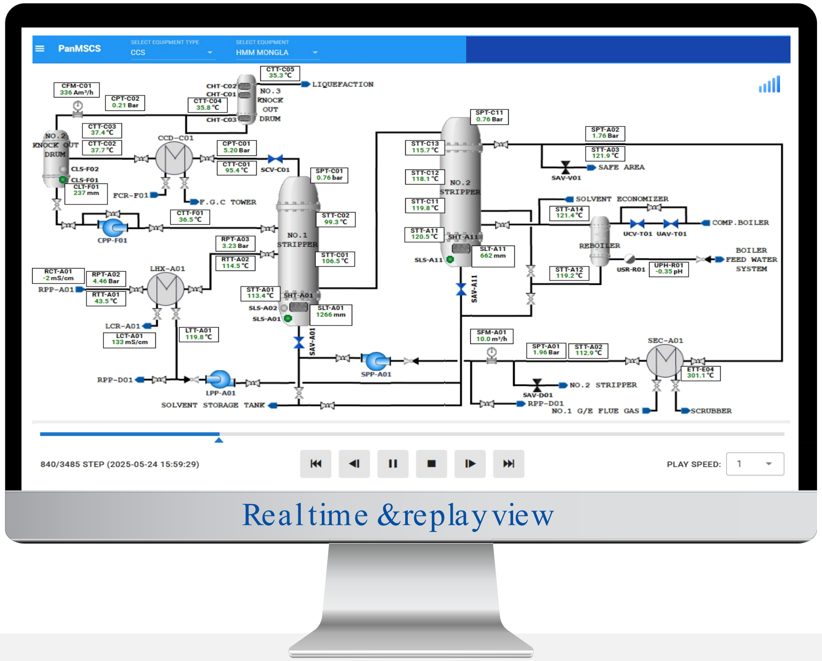
Triple point and Critical point

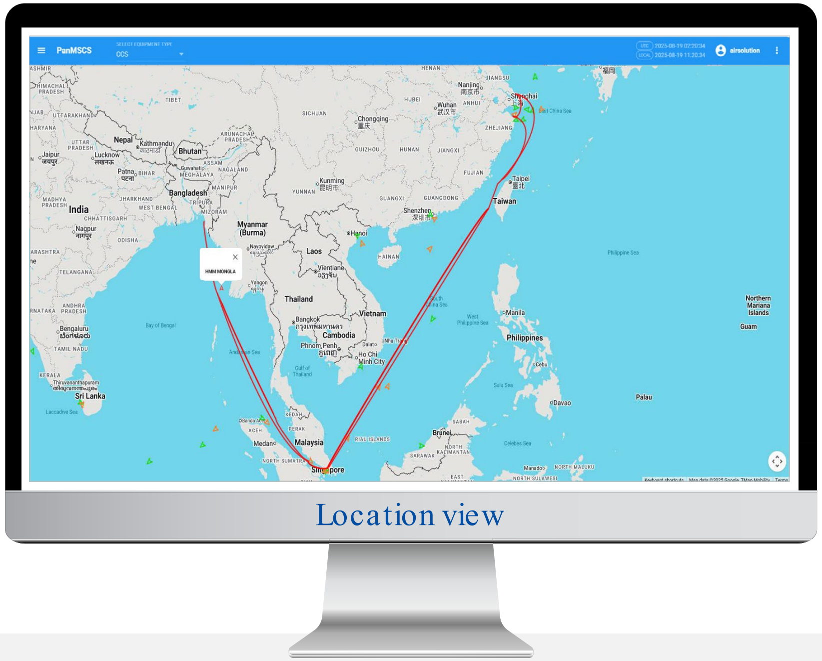


	Low Pressure	Conventional	Unit
Pressure	7 ~ 8	15 ~ 20	bar(a)
Boiling Temperature	-49 ~ -46	-29 ~ -20	℃
Density	1152 ~ 1140	1070 ~ 1029	kg/m^3
Storage Efficiency	High	Low	
Dry Ice Possibility	High	Low	
Tank Cost	Low	High	

3. Technical Challenges I Supporting Crews

Real-ship OCCS project was designed not only perform its functionality but beyond through on-line support


Real time & replay view


Location view

☑ Minimize extra work for crews

new system to crews can cause extra workload to operate

☑ Safety of crews and ships

simultaneously monitor the system from the ship and manufacturer.

☑ Providing a guide

Immediate support can be provided when necessary.

Voyage Summary of HMM MONGLA during Past 1 Year

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Liquefaction Set-up

Flexible Line Purging & Valve Arrange

HMM Safety Check

Voyage Summary of HMM MONGLA during Past 1 Year

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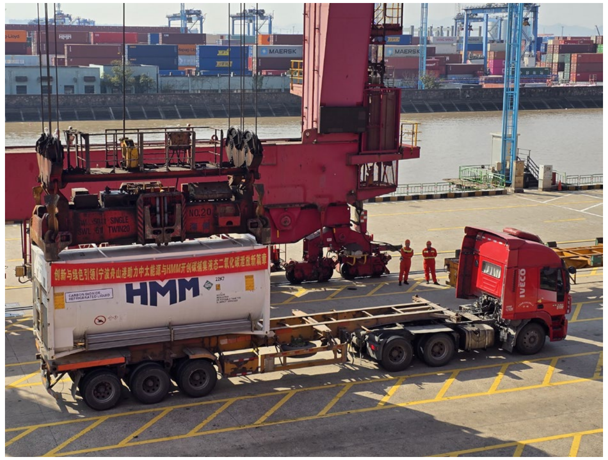
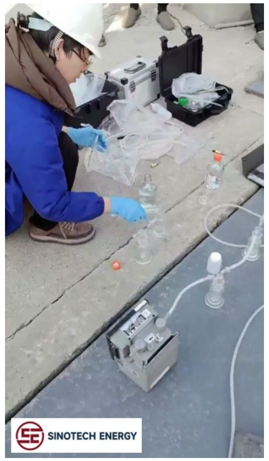
LCO2 offloaded at the port and brought to produce Green Methanol





No.	Date	Route	Detail Performance
1	Jul 12 – Aug 4, 2024	MOK – NGB – SHA – CGP	Initial setup, installation inspection
2	Sep 12 – Oct 19, 2024	SIN – NGB CGP – PKL - SIN	Testing capture system
3	Oct 19 – Nov 22, 2024	SIN – NGB CGP - SING	Testing liquefaction system
4	Nov 22 – Nov 30, 2024	SIN – NGB	Operating full OCCS and LCO_2 storage
5	Dec 31, 2024 – Jan 6, 2025	SIN – NGB	**Off-loading (17/16Ton)**
6	Feb 1 – Feb 9, 2025	SIN – NGB	OCCS Notation
7	Apr 16 – Apr 24, 2025	SIN – NGB	Operating full OCCS and LCO_2 storage
8	May 19 – May 25, 2025	SIN – NGB	**Off-loading (15/10Ton)**
9	Jul 22 – Jul 3, 2025	SIN – NGB	Maintenance

Off loading LCO_2

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Real-ship results, optimized design, and regulatory compliance combine to complete the total solution.

PROPERTY	METHOD	RESULT UNITS	MIN	MIX
Carbon Dioxide	GB/T 1886.228-2016	> 99.9% (V/V)	--	-
Water by Dew Point	GB/7 5832.2-2016	2.14ppm (v/v)	-	-

SGS

SAMPLING REPORT

Client	:	SINOTECH CCS CO.,LTD
Report No.	:	COPCSH2500133-01B2
Date of Job	:	13-Jan-2025 To 13-Jan-2025
Client's Ref.	:	N/A
Vessel	:	N/A
Cargo	:	Carbon dioxide
Location	:	Ningbo, China
Date of Report	:	13-Jan-2025
Page No.	:	2

Sampling Method: ASTM D1265-23a

DATE	SAMPLE DESCRIPTION			CONTAINERS		SAMPLE TYPE	SEAL NO. (SGS-OGC)
	STATUS	SOURCE	PURPOSE	QTY	Type		
13-Jan-2025	-	CICU3881767	Analysis	2*1L	Cylinders	Tap	-
13-Jan-2025	-	CICU3881767	Analysis	1*3L	Vapor bags	Tap	-

Weather condition during sampling:

☑ Normal

☐ Abnormal weather condition: ____________

Unless otherwise instructed, the above samples will be retained only for -

Authorised Signatory
SGS-CSTC Standards Technical Services (Shanghai) Co., Ltd.

	METHOD	RESULT	UNITS	MIN	MAX
Carbon Dioxide	GB/T1886.228-2016	>99.9	% (V/V)	--	--
Water by Dew Point	GB/T 5832.2-2016	2.14	ppm (v/v)	--	--
Hydrogen Sulfide	ASTM D5504-20	<0.1	mg/m³	--	--
Sulfur Dioxide	ASTM D5504-20	<0.1	mg/m³	--	--
Methanethiol	ASTM D5504-20	<0.1	mg/m³	--	--
Ethanethiol	ASTM D5504-20	<0.1	mg/m³	--	--
2-Propanethiol	ASTM D5504-20	<0.1	mg/m³	--	--
Carbonyl Sulfide	ASTM D5504-20	<0.1	mg/m³	--	--
Dimethylsulfide	ASTM D5504-20	<0.1	mg/m³	--	--
Diethylsulfide	ASTM D5504-20	<0.1	mg/m³	--	--
Total Sulfur	ASTM D5504-20	<1	mg/m³	--	--
Ammonia as NH_3	HJ 535-2009	<1	mg/m³	--	--
Formaldehyde Content	HJ 601-2011	<1	mg/m³	--	--
Acetaldehyde	ASTM D7423-23	<1	mg/kg	--	--
Hydrogen	GB/T 9722-2023	<50	ppm (v/v)	--	--
Nitrogen	GB/T 9722-2023	<0.01	% (V/V)	--	--
Carbon monoxide	GB/T 9722-2023	<0.01	% (V/V)	--	--
Oxygen	GB/T 9722-2023	<10	ppm (v/v)	--	--
Mercury Content	EPA 7473-2007	<100	ng/m³	--	--
NOX (NO+NO2)	ASTM D4599-21	11.6	mL/m³	--	--

-------------------------------- End of Analytical Results --------------------------------

GreenMEOH

Declaration of CO_2 Utilization

二氧化碳利用声明

I. Purpose of CO_2 Utilization 二氧化碳利用目的

CO_2 is an essential raw material in our methanol production process. By incorporating CO_2 into our manufacturing operations, we aim to not only produce high-quality methanol but also contribute to the reduction of greenhouse gas emissions through a circular economy approach.

二氧化碳是甲醇生产过程中的关键原材料。通过将二氧化碳纳入我们的生产运营，我们不仅旨在生产高质量的甲醇，还希望通过循环经济模式为减少温室气体排放做出贡献。

II. Source of CO_2 二氧化碳来源

The CO_2 utilized by GreenMEOH is sourced from the Onboard Carbon Capture System with purity over 99.9% (v/v), which is reliable and compliant with all relevant environmental and safety regulations.

本次合作醇美科技使用的二氧化碳来自船舶碳捕集系统，该来源可靠且符合所有相关的环境和安全法规。

III. Utilization Amount of CO2 二氧化碳利用量

- 1st Offloading: 32.2 tons 第一次泄放：32.2 吨
- 2nd Offloading: 24.1 tons 第二次泄放：24.1 吨

Note: The on-site records of the weighing and measurement are provided in the appendix.

注：过磅称量现场记录见附录。

IV. Production Process 生产工艺

The methanol production process of GreenMEOH involves the reaction of CO_2 with hydrogen (H_2) under specific temperature, pressure, and catalyst conditions. The chemical reaction can be simplified as follows: $CO_2+3H_2 \rightarrow CH_3OH+H_2O$. This process is carried out in a state-of-the-art production facility, ensuring optimal conversion rates and product quality.

醇美科技的甲醇生产工艺是在特定的温度、压力和催化剂条件下，使二氧化碳与氢气发生反应。化学反应可简化如下：$CO_2+3H_2 \rightarrow CH_3OH+H_2O$。该工艺在先进的生产设施中进行，确保了最佳的转化率和产品质量。

04

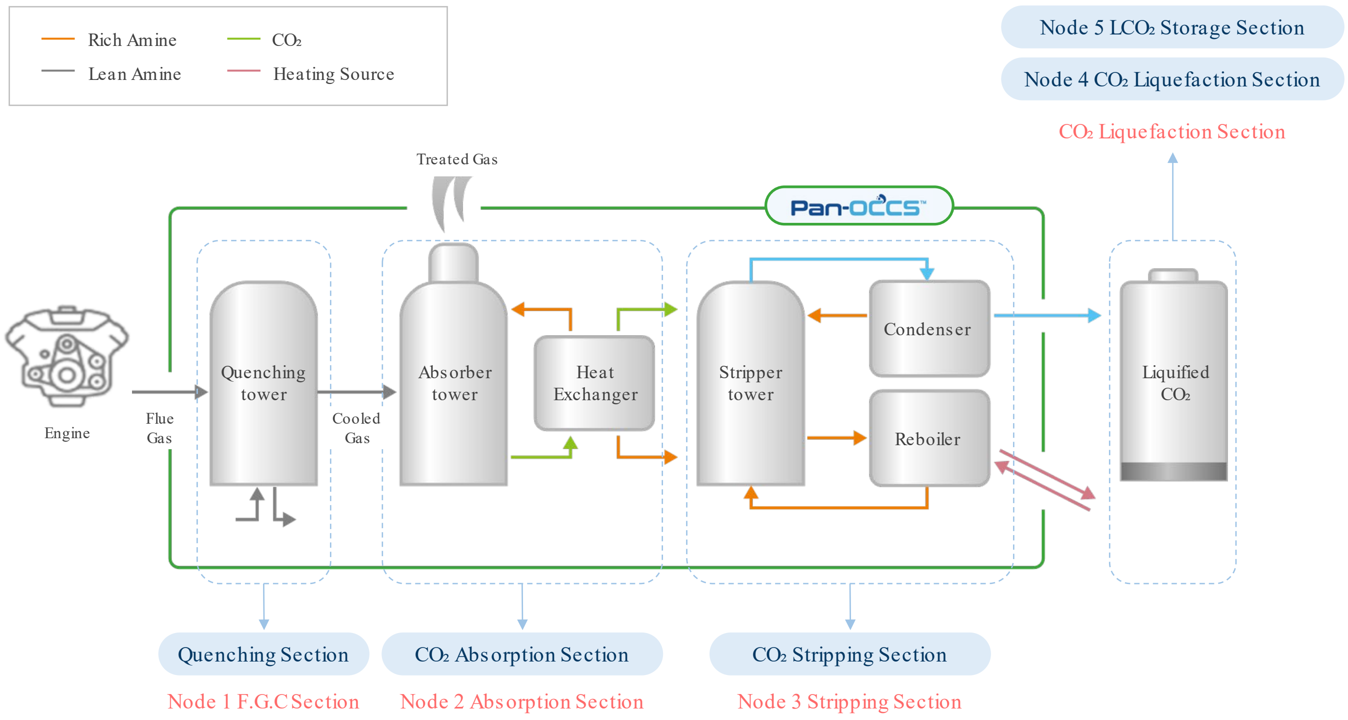
Chapter

Regulatory Gaps and Class Experience

- Regulatory Gaps and Class Experience

Regulatory Gaps and Class Experience

HAZID STUDY



Regulatory Gaps and Class Experience

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HAZID STUDY - Identifying 5 major issues among 252 issues

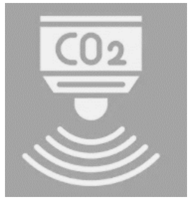
Category	Identified Issue	Measures
Solvent	**Leakage**	- Use of class II pipes with appropriate material - Installation of drip tray liquid detector - Forced ventilation fan in handling space - ESD valve for solvent storage area
	Freezing	- Drain lines for winter season - Heater in solvent storage area
	Personal Accident	- Personal protective equipment (PPE) - Emergency shower and eyewash
CO_2	**Leakage**	- Forced ventilation fan in handling space - CO_2 detector - Installation of vent mast
	Engine Room Ingress	- Separated area from engine room and accommodation
	Freezing	- Pressure control logic and alarm - Set-up procedure for tank connection
	Over-Pressure	- Maximum storage day calculation for BOG
Refrigerant	**Leakage**	- Forced ventilation fan in handling space - Refrigerant detector
Fire	Solvent	- Fire extinguisher (Non-flammability)
	Equipment	- Install fire detectors
	Refrigerant	- Install fixed fire extinguishing system and extinguisher
	Tank	- Water spray for CO_2 tank
Fresh Water Consumption	F.W Shortage	- Apply additional fresh water generator

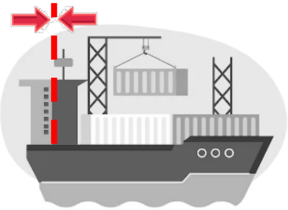
Regulatory Gaps and Class Experience

HAZID STUDY - CO_2 Leakage

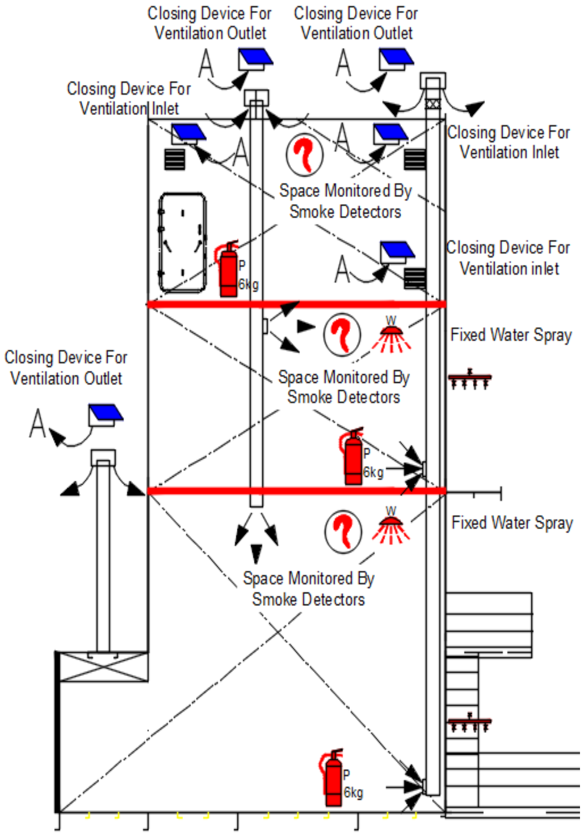
Identified Hazard

Control Measure





Design



Action Taken

CO2 & refrigerant detector

Forced ventilation

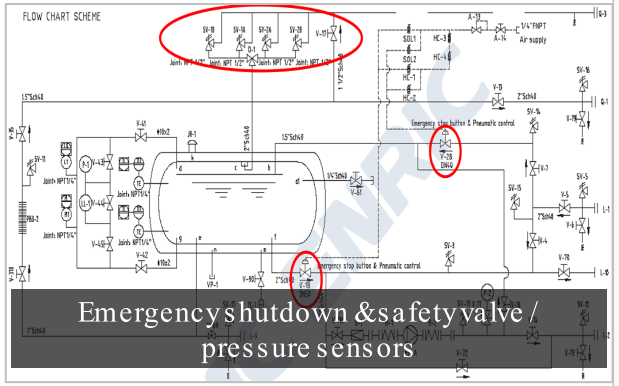
Regulatory Gaps and Class Experience

HAZID STUDY - Liquified CO_2 Tank

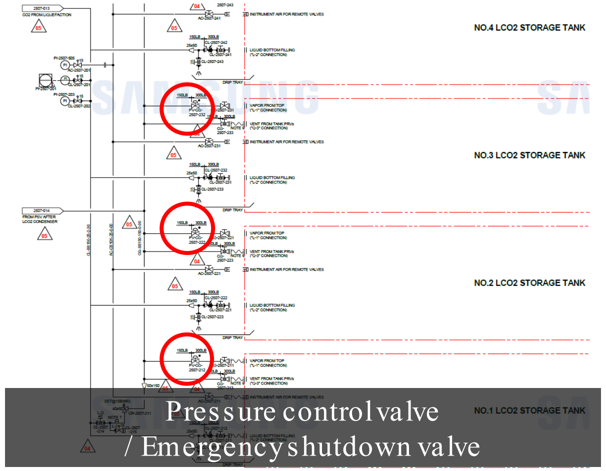
Identified Hazard

Control Measure

Design



Emergency shutdown & safety valve / pressure sensors



Pressure control valve / Emergency shutdown valve

Action Taken

Fixed water spray

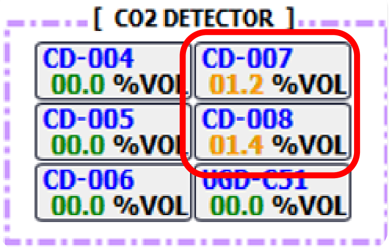
Emergency shutdown valve / safety valve / pressure sensors

Regulatory Gaps and Class Experience

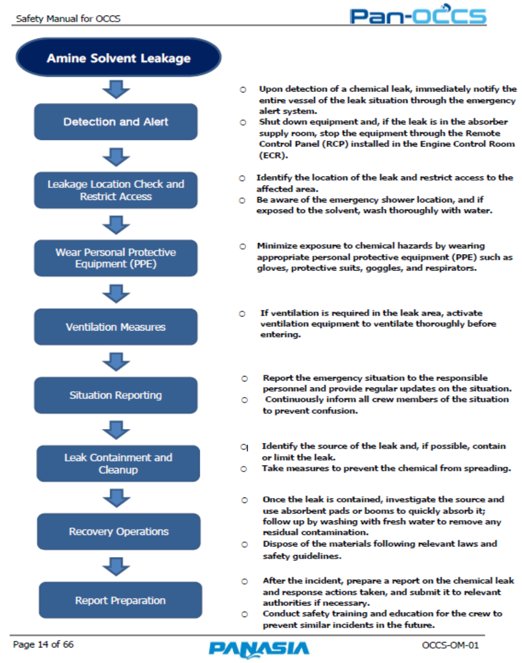
Safety issues and Measures 1 Near miss In Operation

Amine Solvent Leakage


CO2 Leakage

Done Safely in Accordance with the Guidance



Safety Manual for OCCS — Pan-OCCS

Amine Solvent Leakage

Detection and Alert	○ Upon detection of a chemical leak, immediately notify the entire vessel of the leak situation through the emergency alert system. ○ Shut down equipment and, if the leak is in the absorber supply room, stop the equipment through the Remote Control Panel (RCP) installed in the Engine Control Room (ECR).
Leakage Location Check and Restrict Access	○ Identify the location of the leak and restrict access to the affected area. ○ Be aware of the emergency shower location, and if exposed to the solvent, wash thoroughly with water.
Wear Personal Protective Equipment (PPE)	○ Minimize exposure to chemical hazards by wearing appropriate personal protective equipment (PPE) such as gloves, protective suits, goggles, and respirators.
Ventilation Measures	○ If ventilation is required in the leak area, activate ventilation equipment to ventilate thoroughly before entering.
Situation Reporting	○ Report the emergency situation to the responsible personnel and provide regular updates on the situation. ○ Continuously inform all crew members of the situation to prevent confusion.
Leak Containment and Cleanup	○ Identify the source of the leak and, if possible, contain or limit the leak. ○ Take measures to prevent the chemical from spreading.
Recovery Operations	○ Once the leak is contained, investigate the source and use absorbent pads or booms to quickly absorb it; follow up by washing with fresh water to remove any residual contamination. ○ Dispose of the materials following relevant laws and safety guidelines.
Report Preparation	○ After the incident, prepare a report on the chemical leak and response actions taken, and submit it to relevant authorities if necessary. ○ Conduct safety training and education for the crew to prevent similar incidents in the future.

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Future Improvements

Minimizing Leakage of Solvent & CO_2

- Minimizing flanged connection
- Minimizing instruments
- Optimizing piping routes

Regulatory Gaps and Class Experience

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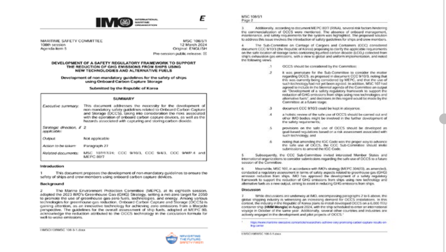
ROK's Past Activities and Future Plans at the IMO

Proposal - IMO guideline

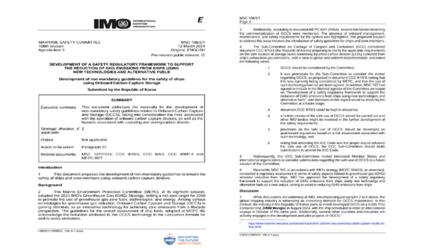


MSC 109 Presentation

OCCS Technical Seminar

CCC9 → MSC 108 → MSC 109 → MSC 110 → CCC 11 → CCC 12 → OCCS Guideline

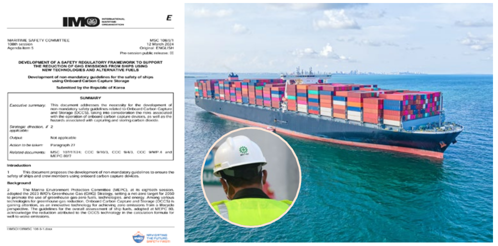
Proposal - UI CO2 Tank



HMM MONGLA installation

INF - HAZID Report

Proposal Plan based on real experience



05

Chapter

Conclusion

Conclusion – Optimized Resolution

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Through this Project, We aim to develop safe and efficient OCCS to achieve decarbonization.

Safety

- Through HAZID study, Safety Rule developed
- Real time monitoring provide safety.

Training

- Land base support can make crew less burdened

Value Chain

- Unloaded CO_2 and Utilized it as Methanol

Efficiency

- High efficiency Carbon Capture with waste heat recovery.

Space

- Minimize the required space for OCCS.

" True progress in decarbonization comes from innovation, collaboration, and shared responsibility. "

Thanks for your attention

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