CO2 Carriers Safety and Design Aspects

October 2022

American Bureau of Shipping

- Mission:
  - To serve the public interest as well as the needs of our members and clients by promoting the security of life and property and preserving the natural environment
  - Not-for-profit company founded in 1862
  - ISO 9000 Certified, Non-governmental Organization
  - Managed through an industry-based (commercial and government) committee structure
  - About 4000 employees
  - 280 million gross tons, comprising over 11,000 marine platforms

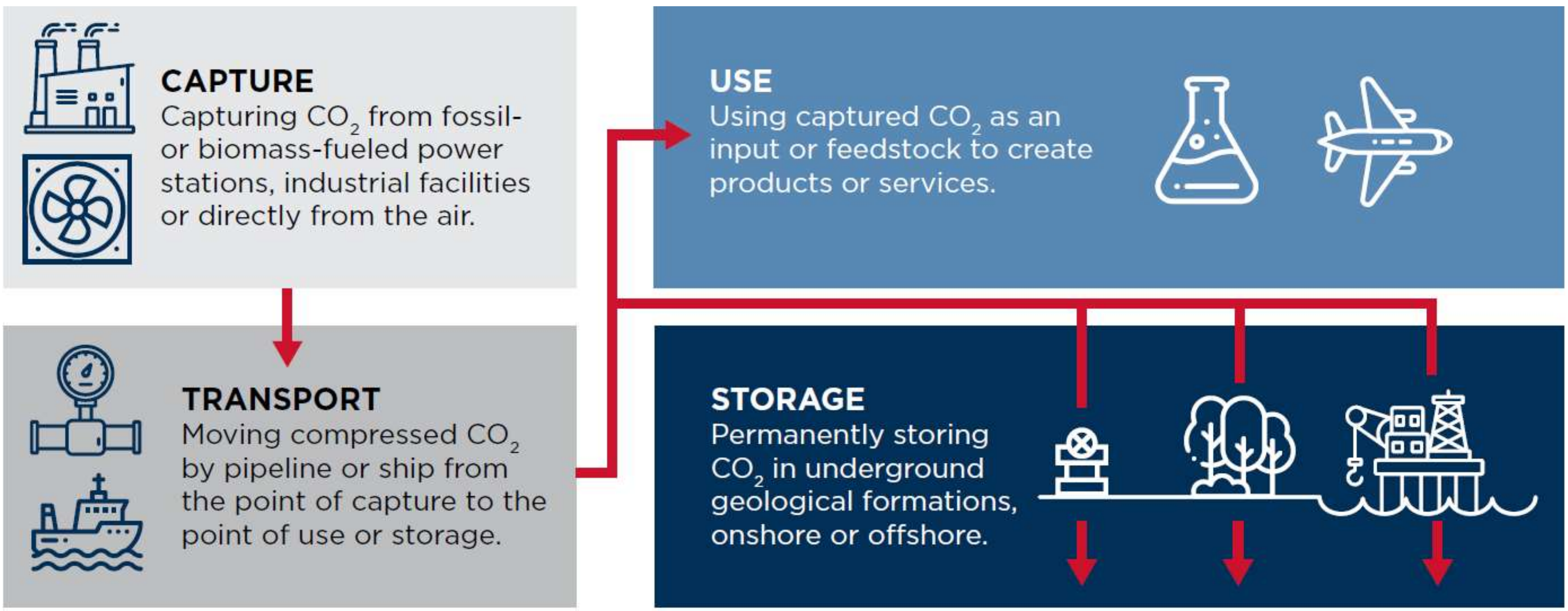
Safety


AT WORK
AT HOME
ABS
TAKE
5
LOOK
BEGIN
THINK
CONTROL
RECOGNIZE

Cryogenic Fluid Safety

- CO_2:
  - Cryogenic Hazard
    - Need proper PPE
  - Asphyxiant
  - Heavier than air
    - Adequate ventilation
    - Similar safeguards to CO_2 fire suppression systems

Carbon Capture, Utilization and Storage Value Chain



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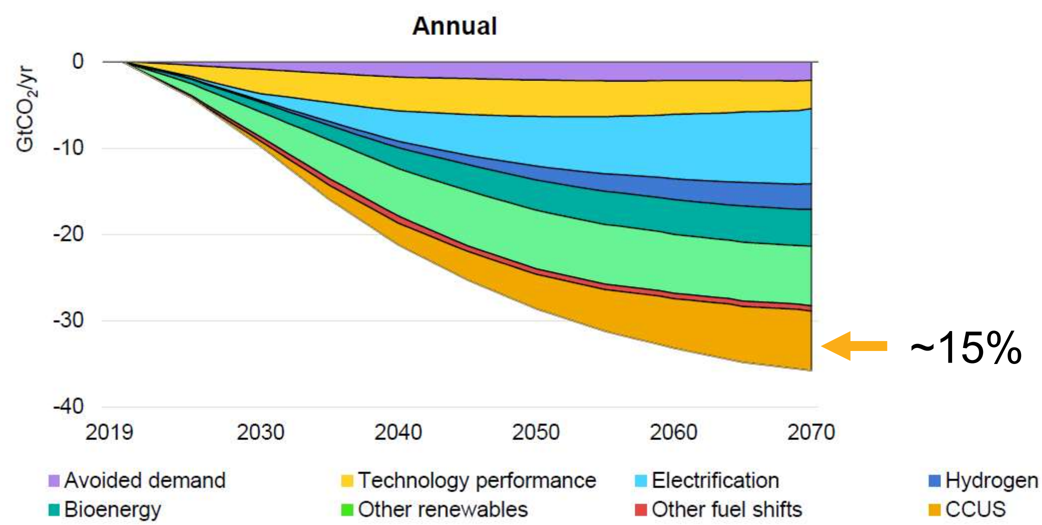
Why CCUS

Carbon Capture, Utilization and Storage (CCUS) is essential to achieving net-zero emissions since it will contribute to nearly 15% of the cumulative reduction needed by 2070.

- Carbon intensive industries
- Enables hydrogen production
- Enables direct extraction of CO_2 from the atmosphere



Source: adapted from IEA, Energy Technology Perspectives 2020, Paris, France.

Shipping's Role in the CCUS Value Chain

CAPTURE

Onboard carbon capture systems are becoming increasingly important for meeting the shipping industry's commitment to reduce greenhouse gas emissions. Hydrocarbon-fueled ships will be in service in the coming years, so onboard CCS will be necessary in order to avoid excess pollution until zero-carbon fuels become viable options.

TRANSPORT

Innovative shipping infrastructure has to be established that could **transport CO_2 efficiently and economically** across long distances then this would represent an essential step towards solving the global problem.

UTILIZATION

Shipping has an opportunity to lead the way in adopting e-fuels to compete the value chain.

Evolving Fuels

gCaptain

“With dual-fuel engines able to operate on carbon neutral green methanol, the six vessels are expected to generate annual CO_2 emissions savings of around **800,000 tonnes** compared to conventionally-fueled ships.

All **19 of the newbuilds** will save around 2.3 million tonnes of CO_2 from entering the atmosphere each year.”

Illustration courtesy Maersk

Maersk Places Order for Six of its Largest Methanol-Powered Containerships Yet

Mike Schuler

Total Views: 5528

October 5, 2022

Source: gCaptain

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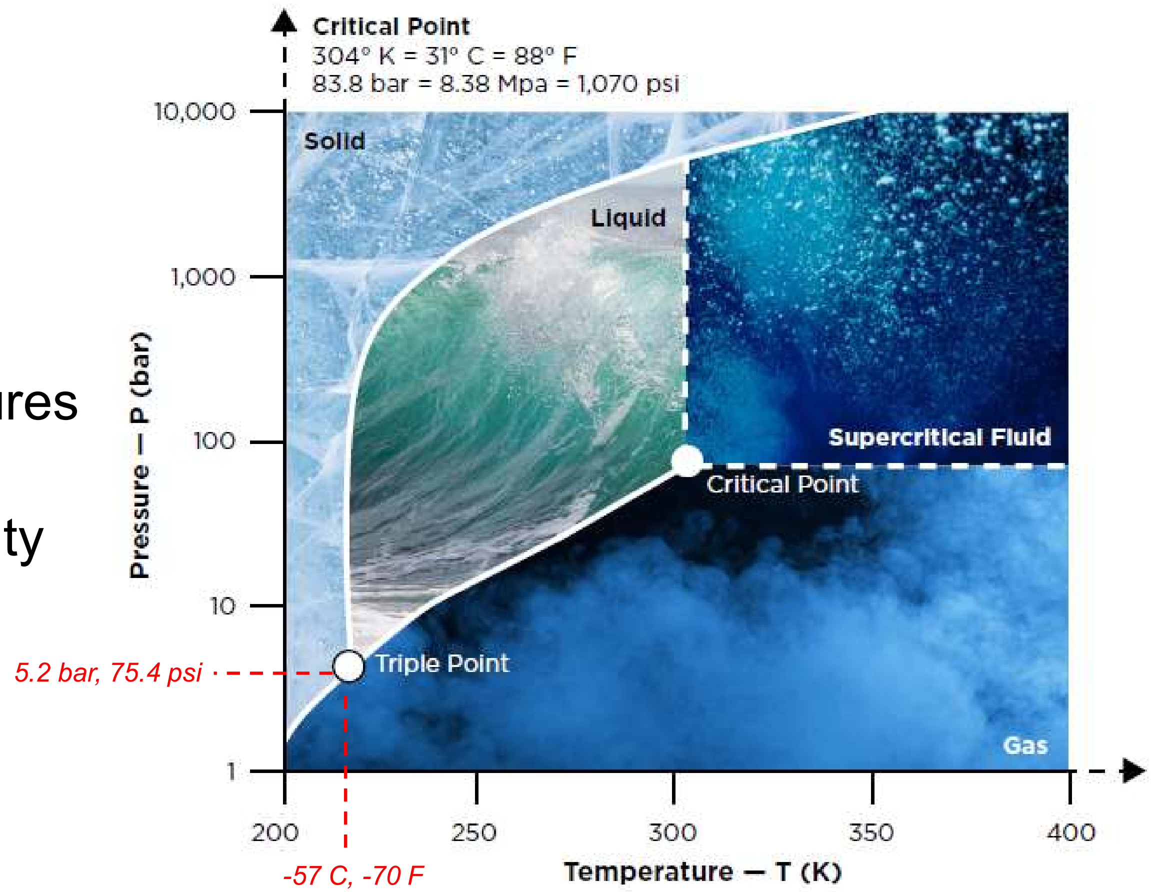
CO2 Characteristics and Phase Diagram

- CO2:
  - Not flammable
  - Asphyxiant
  - Heavier than air
  - Static electricity build-up
- Liquid CO2 cannot exist at pressures below triple point
- Triple Point Depends on CO2 purity (-57°C, 5.2 bar for pure CO2)



CO2 Carrier Safety Considerations

Triple Point & Dry Ice

- The carbon dioxide must be carried within a temperature and pressure range that will prevent formation of solid CO_2 (dry ice) and not exceed the maximum allowable relief valve settings (MARVS) of the ship's cargo tanks.
  - Only Type C pressurized tanks can be used to maintain in liquid state (no option for atmospheric pressure storage).
  - Close proximity to triple point requires additional redundancies & operational fail safes to ensure cargo does not solidify into dry ice
  - Engineering around operational and design tank pressure should consider margins around formation of dry ice near triple point.
- If the temperature at saturation falls below -56.6 C, the CO_2 can solidify into dry ice which could damage cargo pumps and tank internals, block piping and valves (including safety relief valves), and cause delays in vessel and terminal operations.

CO2 Carrier Safety Considerations

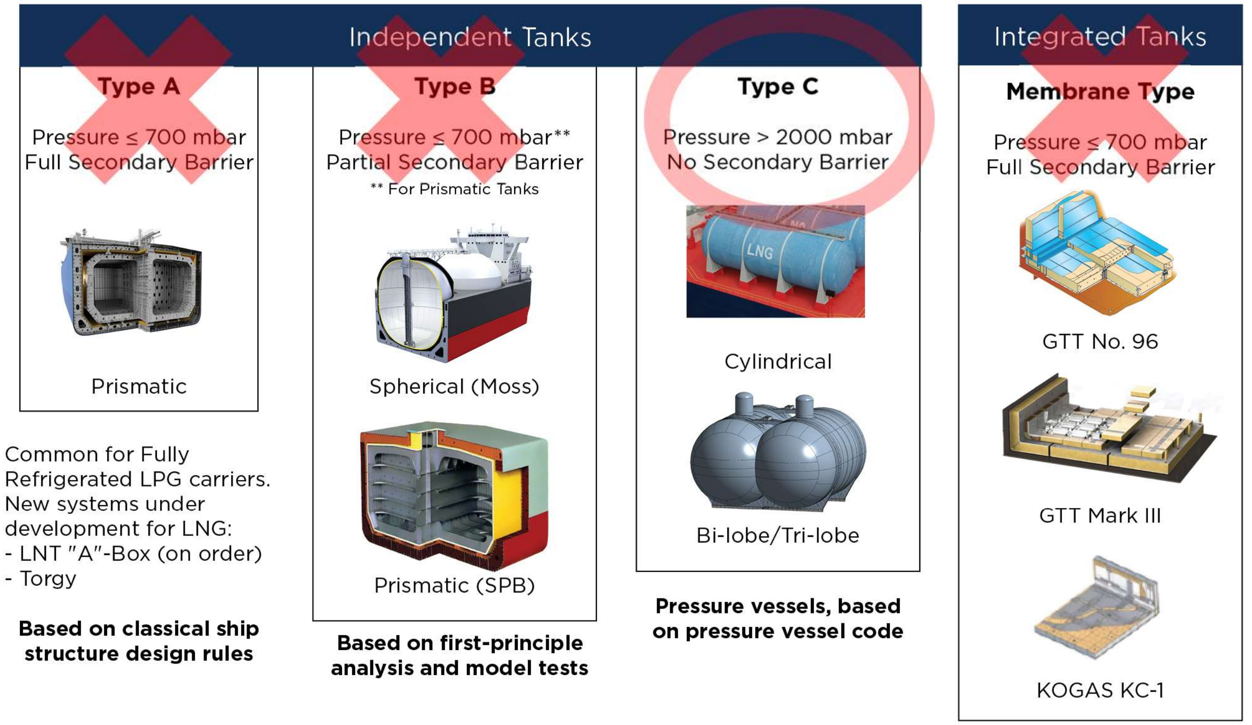
Venting

- If the CO2 is allowed to warm, it could exceed the pressure setting of the safety relief valves resulting in venting of the CO2 vapor to atmosphere.

Density

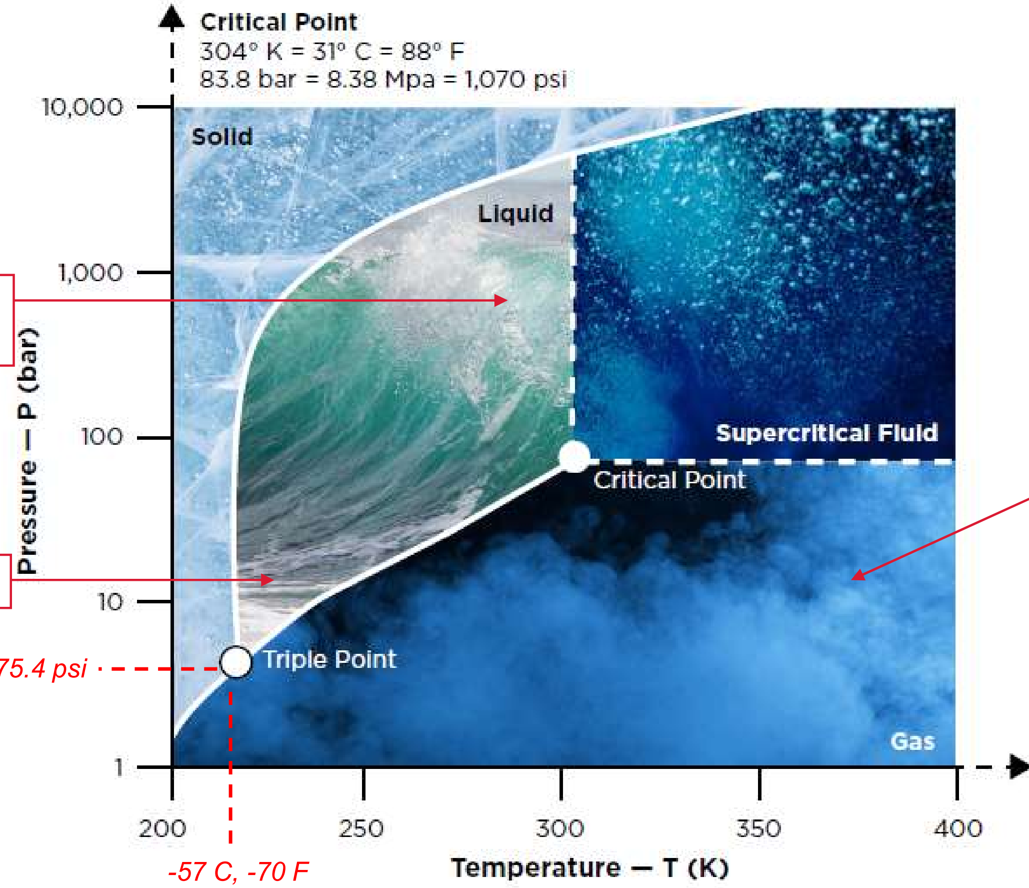
- CO2 is **heavier than air**. Carbon dioxide vapors released into the atmosphere will accumulate in the area adjacent to the release. The highest concentration of carbon dioxide vapor will be found at the lowest point in the release area.

IMO Classification of Gas Carriers



Cargo to be maintained above triple point => Pressure Vessel

CO2 Characteristics and Phase Diagram



Smaller, thicker tanks, little to no insulation

Bigger tanks, lots of insulation

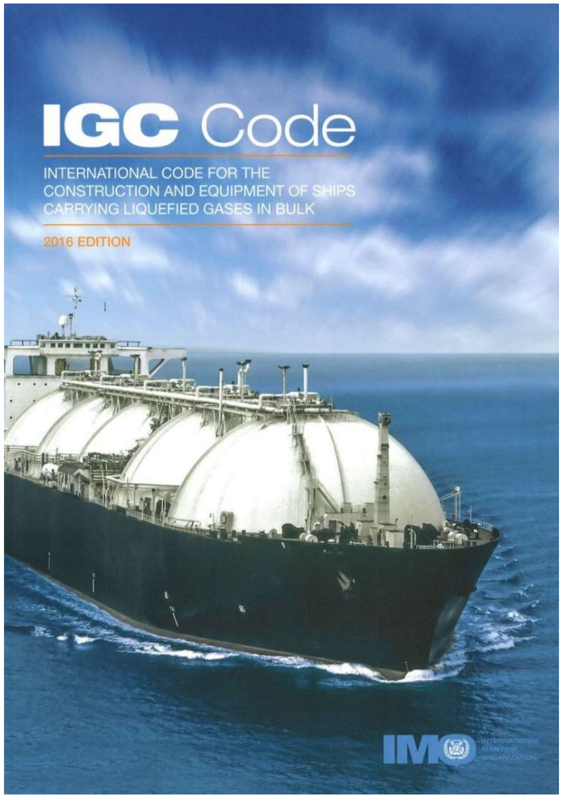
Smaller, thicker tanks, no insulation

Example of Low-Pressure Storage

Conceptual image of Mitsubishi Shipbuilding Co.'s liquefied CO2 demonstration test ship
Source: Mitsubishi Shipbuilding Co. & Bloomberg.com

Rules & Regulations for CO2 Carriers

- International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code)
- ABS Marine Vessel Rules



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IGC Specific Requirements for CO_2

IGC 17.21

- Risk of **cargo freezing:**
  - Low Pressure alarm at least 0.05 MPa (7 psi) above triple point.
  - On Low Pressure, automatic closure is required for cargo manifold liquid and vapor valves and stop all cargo compressors and cargo pumps.
  - Means of isolating the cargo tank safety valves shall be provided.
  - Discharge piping from safety relief valves shall be designed so they remain free from obstructions that could cause clogging.
  - Protective screens shall not be fitted on vent outlets.
  - Minimize vent pipe length and avoid excessive bends or T-pieces.
  - Consider the temperature drop in the vent line.
- All **materials** used in cargo tanks and cargo piping system shall be **suitable for the lowest temperature** that may occur in service (saturation temperature at set pressure of the automatic safety system).
- **Continuous monitoring for CO_2 build-up** for cargo hold spaces, cargo compressor rooms and other enclosed spaces where CO_2 could accumulate (**CO_2 asphyxiant**).
  - Permanent fixed gas detection even if the ship has type C cargo containment.

IGC Specific Requirements for CO_2

IGC 17.22

- In case of reclaimed quality, the materials of construction used in the cargo system shall also take account of the possibility of corrosion, in case the reclaimed quality carbon dioxide cargo contains impurities such as water, sulphur dioxide, etc., which can cause **acidic corrosion** or other problems.

IGC 13.2.3.4

- Restricted level gauging system is allowed.

.4 restricted devices which penetrate the tank and, when in use, permit a small quantity of cargo vapour or liquid to escape to the atmosphere, such as fixed tube and slip tube gauges. When not in use, the devices shall be kept completely closed. The design and installation shall ensure that no dangerous escape of cargo can take place when opening the device. Such gauging devices shall be so designed that the maximum opening does not exceed 1.5 mm diameter or equivalent area, unless the device is provided with an excess flow valve.

a Product name	*b*	*c* Ship type	*d* Independent tank type C required	*e* Control of vapour space within cargo tanks	*f* Vapour detection	*g* Gauging	*h*	*i* Special requirements
Acetaldehyde		2G/2PG	–	Inert	F + T	C		14.4.3, 14.3.3.1, 17.4.1, 17.6.1
Ammonia, anhydrous		2G/2PG	–	–	T	C		14.4, 17.2.1, 17.12
Butadiene (all isomers)		2G/2PG	–	–	F + T	C		14.4, 17.2.2, 17.4.2, 17.4.3, 17.6, 17.8
Butane (all isomers)		2G/2PG	–	–	F	R		
Butane-propane mixture		2G/2PG	–	–	F	R		
Butylenes (all isomers)		2G/2PG	–	–	F	R		
Carbon Dioxide (high purity)		3G	–	–	A	R		17.21
Carbon Dioxide (Reclaimed quality)		3G	–	–	A	R		17.22
Chlorine		1G	Yes	Dry	T	I		14.4, 17.3.2, 17.4.1, 17.5, 17.7, 17.9, 17.13
Diethyl ether*		2G/2PG	–	Inert	F + T	C		14.4.2, 14.4.3, 17.2.6, 17.3.1, 17.6.1, 17.9, 17.10, 17.11.2, 17.11.3

IGS para. 2.1.2.4 - A *type 3G ship* is a gas carrier intended to carry the products indicated in chapter 19 that require moderate preventive measures to preclude their escape.

CO2 carrier technical / operational challenges

- Cargo purity/composition depending on various parameters:
  - Carbon Capture Technology / variety of resources
  - CO2 onshore handling and storage facilities (temperature/pressure conditions)
- BOG management when sailing
  - Pressure accumulation IGC 7.5
    - Operating environmental and cargo loading temperatures
    - Operational profile: loading levels, cruising range, local restrictions (US)
  - Re-liquefaction IGC 7.3
    - Highly depending on CO2 composition
    - Challenge on managing the non-condensables
- Tank pressure control during discharging
  - Compatibility with loading facilities / vapor generation onboard?
- Tank pressure control during cooling down
  - Avoid sharp pressure drops / control tank temperature

CO_2 source Capture technology	Coal-fired power plant Amine-based absorption	Coal-fired power plant Ammonia-based absorption	Coal-fired power plant Selexol-based absorption	Coal-fired power plant Oxyfuel combustion	Natural gas processing Amine-based absorption	Synthesis gas processing Rectisol-based absorption
CO_2	99.8%	99.8%	98.2%	95.3%	95.0%	96.7%
N_2	2000	2000	6000	2.5%	5000	30
O_2	200	200	1	1.6%		5
Ar	100	100	500	6000		
NO_x	50	50		100		
SO_x	10	10		100		
CO	10	10	400	50		1000
H_2S			100		200	9000
H_2			1.0%			500
CH_4			1000		4.0%	7000
C_2+					5000	1.5%
NH_3	1	100				
Amine	1					
	Post	Post	Pre	Oxy	Amine	Amine

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ABS Activities on Carbon Capture

- Whitepaper *Carbon Capture, Utilization and Storage* (Aug 2021)
- Liquified CO_2 carrier designs – several Approvals in Principle, more in progress
- Onboard capture projects underway with shipyards, owners, equipment vendors
- Joint projects to develop CO_2 Injection Offshore Platform for Carbon Capture and Storage
- Supporting University research into onboard carbon capture technology and applications
- Regulatory tracking and input

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ABS CO2 Carriers JDP/AIP

HMD/KSOE

news.cision.com / American Bureau of Shipping / ABS AIP for Next Generation Liquifi...

ABS AIP for Next Generation Liquified CO2 Carrier JDP Designs

WED, SEP 22, 2021 16:49 CET

Report this content

Designs the Result of Six-Month JDP between ABS, Hyundai Mipo Dockyard, Korea Shipbuilding and Offshore Engineering and Republic of the Marshall Islands Maritime Administrator

(**DUBAI**) Liquefied CO_2 carrier designs by Hyundai Mipo Dockyard (HMD) and Korea Shipbuilding and Offshore Engineering (KSOE) have been granted Approval in Principle (AIP) by ABS and the Republic of the Marshall Islands (RMI) Maritime Administrator.

DSME

news.cision.com / American Bureau of Shipping / ABS and DSME to Develop Very La...

ABS and DSME to Develop Very Large Liquefied CO2 Carrier

THU, SEP 16, 2021 15:23 CET

Report this content

JDP Supports Global Adoption of Carbon Capture Technology

Dan-Unity CO2

Design Approval for Large Dedicated CO2 Carriers from ABS

Design plans were approved for two concepts for large CO2 carriers (Dan-Unity file photo)

PUBLISHED NOV 24, 2021 7:52 PM BY **THE MARITIME EXECUTIVE**

Efforts are continuing to develop a new, dedicated shipping operation that will play a key role in the proposed carbon capture storage and reuse projects currently proposed to help large industrial companies meet the goals to reduce harmful CO2 emissions. A Danish startup company, Dan-Unity CO2, reports that it has received design approvals from the American Bureau of Shipping for what may become the first dedicated CO2 carrier.

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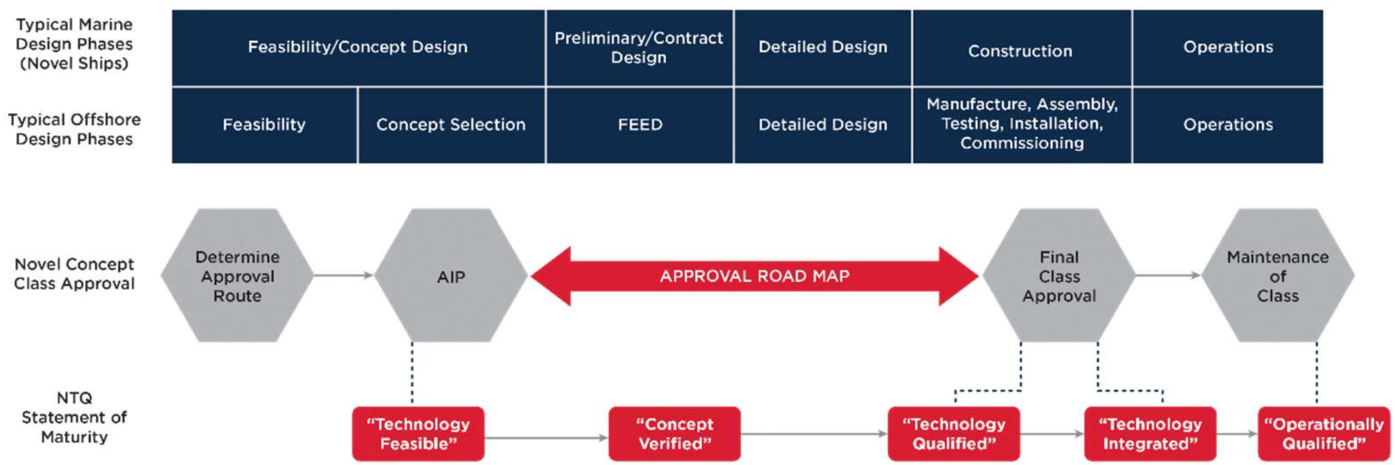
Novel Concept Approval vs New Technology Qualification

New Technology Qualification

- Early stage of design
- Intended for new technology (System, subsystem, equipment, component)
- Statement of Maturity
- Leading to PDA/Type approval

Novel Concept Approval

- Early stage of design
- Intended for assets with novel concept
- Approval in Principle (AiP)
- Leading to final classification



Thank You

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