



Materials Performance in Liquid CO₂ for Maritime Transport **MARCO₂**

Call to participate
in **JOINT INDUSTRY PROJECT**

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Challenge

The deployment of liquid CO₂ (LCO₂) transport in the maritime sector is advancing rapidly in support of large-scale carbon capture and storage (CCS) developments; however, robust technical evidence required to ensure safe, reliable, and economically optimized shipboard storage and transport remains limited.

The requirements of the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, IMO circulars and related standards have limited provisions for corrosion testing and materials qualification for carbon steels exposed to impurity-containing liquid CO₂ under representative maritime service conditions. This JIP call presents a structured process to address the identified gap, by delivering a comprehensive framework that provides assurance in material selection and performance, safeguarding both asset integrity and environmental safety.

Uncertainty regarding the impact of impurities on LCO₂ phase behaviour, corrosion kinetics, and materials compatibility has resulted in highly conservative design and operational constraints. Current industry guidance for LCO₂ transport relies heavily on project-specific impurity specifications notably those developed for the Northern Lights project, including a 1.5 ppmol NO_x limit widely regarded as excessively restrictive. These conservative limits increase system complexity and capital and operational costs. Simultaneously, elevated concentrations of SO_x, NO_x, O₂, H₂S, and H₂O can accelerate localized corrosion, promote stress corrosion cracking and drive materials degradation, increasing inspection and maintenance demands and the risk of corrosion-induced failures.

Stakeholders in the CO₂ ship transport sector lack validated corrosion and performance data for carbon steels exposed to impurity-containing liquid CO₂. This gap has led to overly conservative impurity limits, raising costs and uncertainty in material supply, shipbuilding, and LCO₂ transport, while also limiting regulators' ability to set proportionate, risk-based material assurance standards.

A previous study by TWI and Lloyd's Register (herein referred to as LR) identified the need to validate predictive models using laboratory-generated experimental data for low pressure/ low temperature conditions. Currently, limited experimental data exists for the specified low temperature/ low pressure triple point conditions. This lack of validation data introduces uncertainty in model accuracy and reliability. Targeted laboratory testing is therefore required to generate benchmark data, reduce technical risk, and ensure confidence in model predictions.

JIP scope

The current JIP scope is limited to low-temperature/low-pressure conditions (approximately -55°C and 8 bar) in line with the indicative budget and programme.

Subject to sufficient participant interest, medium-pressure conditions (approximately -35°C and 15 bar) may be considered under a separate funding structure. While modelling of medium-pressure scenarios could be incorporated within the present JIP scope, any associated experimental testing would be undertaken as part of a separately funded project.

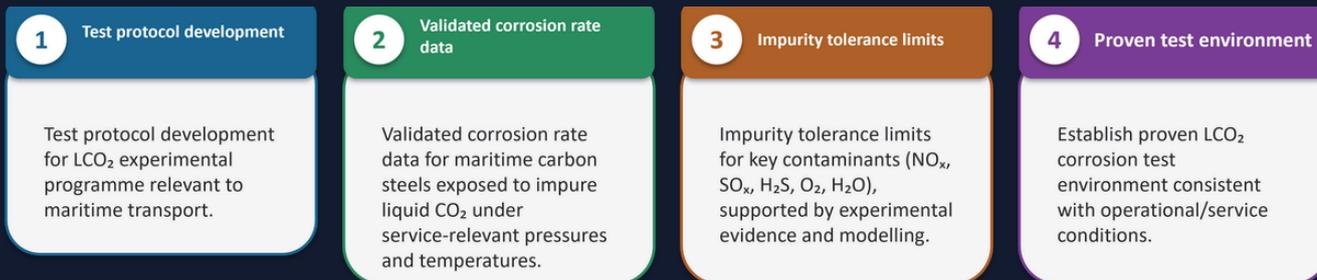
Solution

MARCO₂ will be jointly led by LR and TWI. This project offers a regulator-aligned, industry-led experimental programme to address the critical evidence gap limiting the deployment of carbon steels for use in low temperature/ low pressure liquid CO₂ transport containment systems. The project integrates experimental testing of carbon steels in impurity-containing liquid CO₂ under service-representative conditions with detailed electrochemical and post-exposure corrosion analysis. The focus will be on realistic multi-component impurity combinations and concentrations at low temperature/ low pressure maritime storage conditions (approximately -55°C and 8bar) representative of near-triple point shipboard operation.

Stakeholder benefit/ value proposition

Benefits/ Value	Shipbuilders	Ship Owners / Operators	Steel Manufacturers	Welding Consumable Manufacturers	Material Testing Laboratory	Emitters	Terminal Infra-structure Operators
Reduced technical uncertainty through validated corrosion and performance data for carbon steels in impure LCO ₂ relevant to maritime transport.	✓	✓	✓	✓	✓		✓
Evidence-based impurity tolerance limits enabling less conservative design and operation, and reduced risk of failures, inspection burden, and unplanned maintenance.	✓	✓	✓	✓		✓	✓
Increased industry confidence in the safe and scalable deployment of LCO ₂ transport infrastructure.	✓	✓				✓	✓
Investment leverage and market positioning, supporting access to low-carbon funding, investor confidence, and potential incentives for sustainable shipping solutions.	✓	✓	✓	✓	✓	✓	✓
Cost optimization by enabling evidence-based operational limits and reducing over-conservatism.	✓	✓	✓	✓		✓	✓
Sustainability and branding benefits, enhancing Environmental, Social, and Governance (ESG) profiles and demonstrating commitment to decarbonization.	✓	✓	✓	✓	✓	✓	✓
Attractive sponsorship visibility, positioning companies as leaders in emerging low-carbon maritime technologies.	✓	✓	✓	✓	✓	✓	✓
Collaborative knowledge sharing with regulators and industry peers, strengthening technical credibility and access to strategic networks.	✓	✓	✓	✓	✓	✓	✓
Enhanced safety and reliability of LCO ₂ transport systems, reducing the financial risk of failures or downtime.	✓	✓				✓	✓
Lower inspection and maintenance risks through improved understanding of corrosion and degradation mechanisms.	✓	✓	✓	✓	✓		✓
Reduced design and operational uncertainty, enabling more risk-based, cost-efficient engineering decisions and potentially lowering capital and operating expenditures.	✓	✓	✓	✓		✓	✓
Influence on standards and test protocols, helping shape regulatory guidance and impurity limits.			✓	✓	✓		
Early access to critical data on corrosion and materials performance in impure LCO ₂ under service-relevant maritime conditions.	✓	✓	✓	✓	✓		✓
Market differentiation – positions the company as an innovation leader in low-carbon maritime transport, enhancing reputation and long-term competitiveness.	✓	✓	✓	✓	✓		✓
Strategic decision support – provides executives with credible data to justify investments in LCO ₂ transport with lower financial and regulatory risk.	✓	✓				✓	✓

LCO₂ Maritime Transport - Four Pillars of Action



Price and Schedule

The project will run for 18-24 months, commencing in circa Q3/2026 and concluding in 2028.

Participation in the JIP will require a financial commitment from each member to support the overall project execution. The individual contribution level will be determined upon confirmation of the final number of participating organizations. The preliminary total project budget is estimated at GBP 1 million over the project period.

JIP Workshop

A JIP workshop* will be held on 28 April 2026 to discuss and align on the proposed project scope and value proposition, giving stakeholders the opportunity to contribute to its direction and expected outcomes. To register to attend, please sign up here: <https://www.twi-global.com/media-and-events/events-diary/materials-performance-in-liquid-co2-for-maritime-transport>

*The workshop will be offered as a hybrid (online and in-person) event, giving attendees the opportunity to tour the TWI laboratories and state of the art facilities.



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Delivery

The JIP is envisaged to consist of the following work programme:

- WP1: Thermodynamic modelling of multi-component phase behaviour, water activity, and aqueous phase separation
- WP2: Selection of Materials (including base material and welded joints) and impurity containing CO₂ environments
- WP3: Development and execution of controlled corrosion test protocols
- WP4: Quantitative corrosion rate determination, localized corrosion (pitting) analysis, and data integration

Following this WP structure, MARCO₂ will generate corrosion kinetics and materials performance data to directly inform allowable impurity threshold based on measurable degradation rates and defect propagation behaviour. Close engagement with CO₂ vessel operators, equipment suppliers, welding consumable manufacturers, steel manufacturers, ship builders, material testing facilities and industry regulators within the Sponsor group will ensure outputs are immediately actionable, supporting evidence-based specifications, reduction of excessive conservatism, and development of LCO₂ corrosion testing guidance for safe, cost-efficient LCO₂ transport and regulatory certification.

A comprehensive project scoping document will be shared with participants, outlining the detailed technical scope, as well as the proposed timelines and key project milestones.