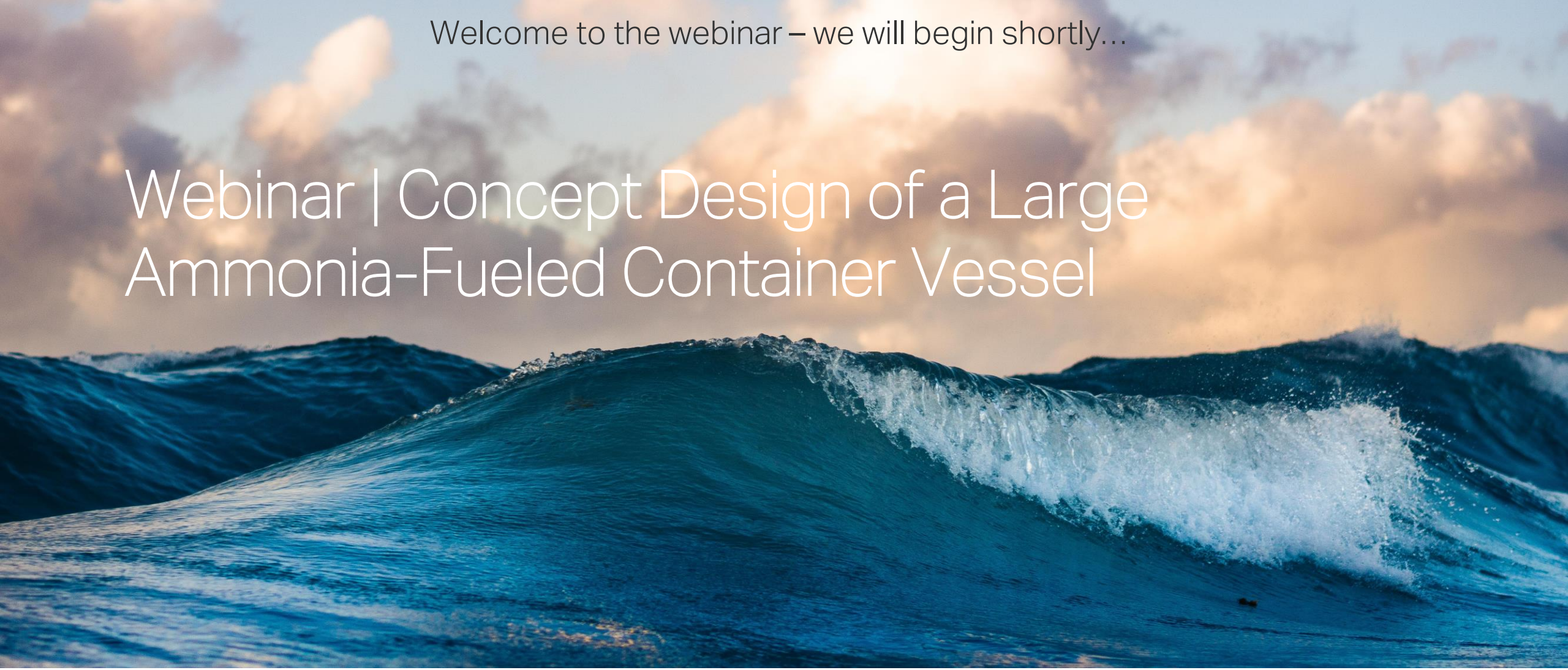
Welcome to the webinar – we will begin shortly…



Webinar | Concept Design of a Large Ammonia-Fueled Container Vessel

seaspan

Mærsk Mc-Kinney Møller Center
for Zero Carbon Shipping

Classification Society:
ABS

Ship Designer:
FORESHIP

On today's agenda:

01 Introduction

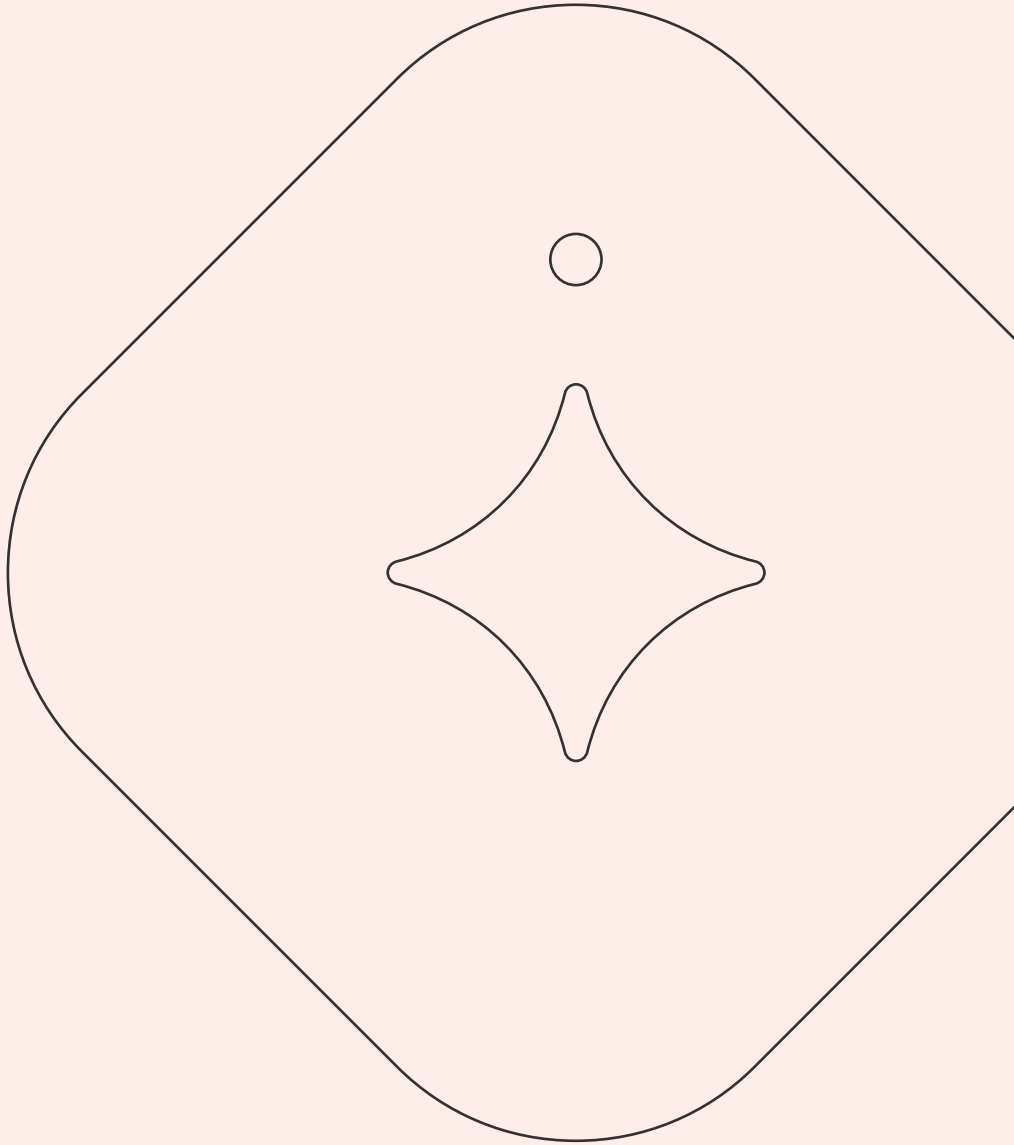
02 Ammonia - a potential fuel pathway for the maritime

03 Concept design: Defining the requirements

04 Concept design: Ship design process

05 Industry perspectives

06 Panel discussion and Q&A



On today's webinar panel

Seb Brindley

Senior Naval Architect

Seaspan Corporation (MMMCZCS Secondee)

Shaun White

Managing Director

Foreship UK Ltd

René Laursen

Director, Fuels & Technology

American Bureau of Shipping (ABS)

Nikolaos Kourtidis

Two-Stroke Promotion & Customer Support

MAN Energy Solutions

Prakash Chandra

Director

Fleet Management Limited

Claus Rud Hansen

Senior Technology Manager

A.P. Moller-Mærsk (MMMCZCS Secondee)

Matt Dunlop

Director of Sustainability and Decarbonization

V.Group (MMMCZCS Secondee)

Thomas McKenney

Head of Ship Design

MMMCZCS

seaspan

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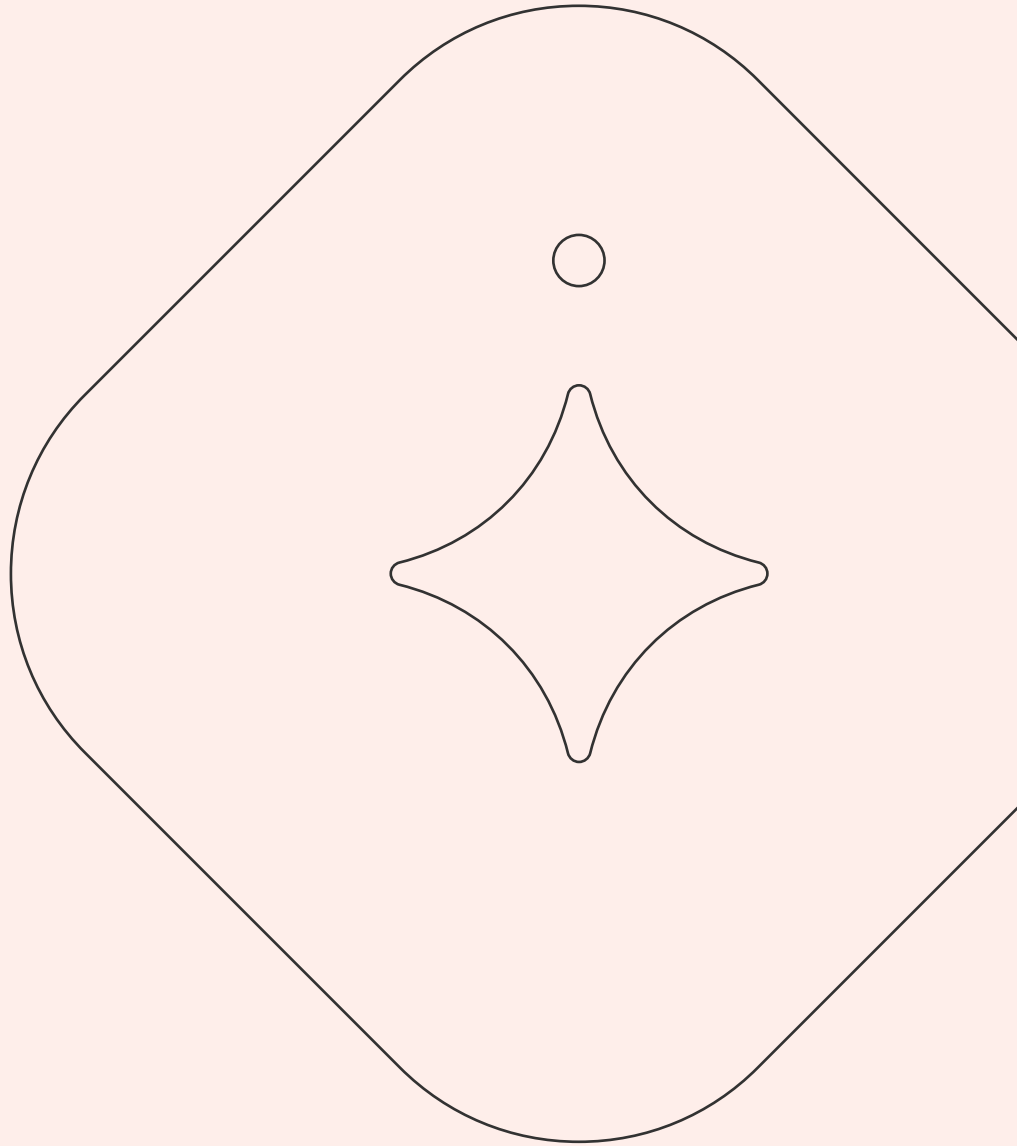
Seaspan & MMMCZCS recently published the report "Concept design of a 15,000 TEU ammonia-fueled container vessel"

- Objectives, requirements, regulations
- Risk assessment
- Concept design
- Fuel consumption and emissions

Download the report and many other publications on www.zerocarbonshipping.com

Ammonia - a potential fuel pathway for the maritime



The industry is on a path to decarbonize - ammonia being a promising marine fuel pathway

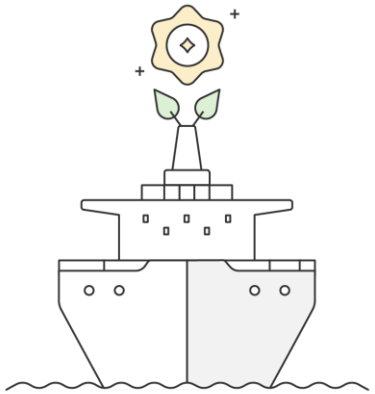
- Ammonia offers a viable and scalable low-emission pathway early in the industry transition.
- Ammonia can be combusted with limited carbon dioxide emissions.
- Novel fuel system technologies (i.e., engines) and ship designs are rapidly developing.
- Maritime industry has experience with gas as fuels and carrying ammonia as cargo.
- Onshore industries possess significant experience in safely handling, transferring, and storing ammonia.

Critical challenges to onboard safety and operations

Ammonia's toxic properties

Absence of harmonized international rules

Ammonia dispersion properties



Development of novel system technologies (i.e., engines and fuel supply systems)

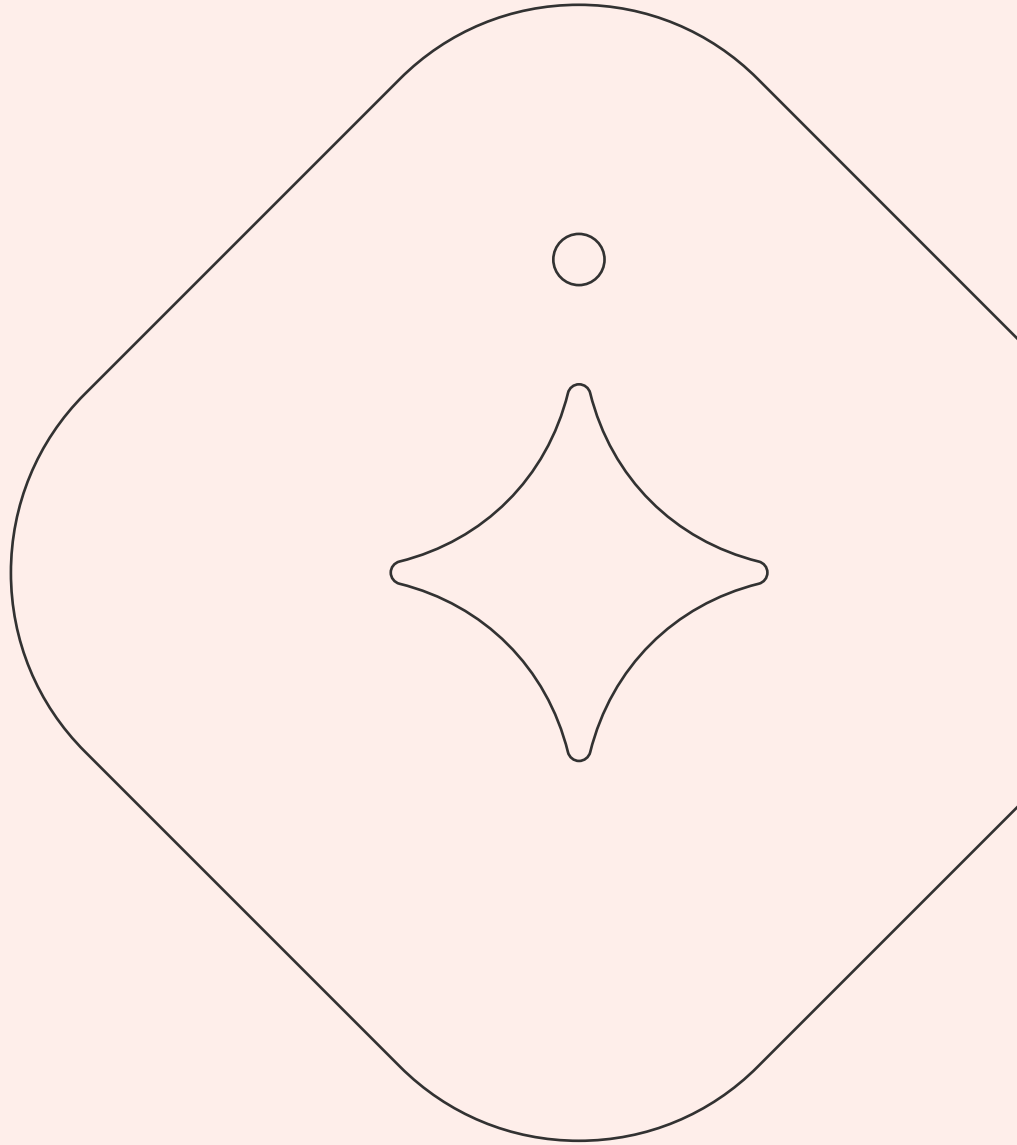
Onboard risks to crew and needed upskilling

Unknown emissions profile (N_2O, NO_X)

Concept design

Concept design: Defining the requirements

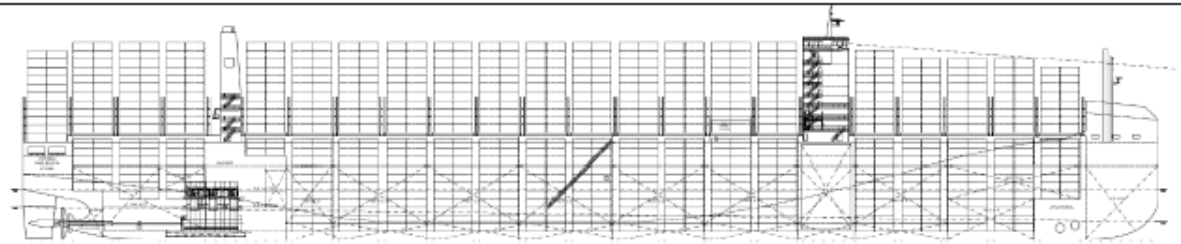
Seb Brindley
Senior Naval Architect
Seaspan Corporation
(MMMCZCS Secondee)



Pocket Plan

15,700 TEU AMMONIA FUELED CONTAINER SHIP

seaspan



Main Particulars

Length, o.a.	approx.	356.0 m
Length, b.p.		350.0 m
Breadth		53.6 m
Depth		30.0 m
Draught, design		15.5 m
Draught, scantling		17.0 m
Air draft	less than	60.0 m
Deadweight, scantling	approx.	181,300 t
Service speed	approx.	20 kn

CLASS: ABS A1, Container Carrier, AMS, ACCU, CPS, BWT, CLP-V, CRC(I), CSC, NBLES, RRDA, TCM, UWILD, LFFS(DFD-Ammonia), RELIQ

Tank Capacities

Ammonia (Type B)	11,600 m^3
VLSFO/ULSFO	4,600 m^3
Ballast Water Storage	57,000 m^3
Fresh Water	530 m^3
Lubricating Oil	430 m^3

Energy Efficiency

Rudder:	Full spade, twisted leading edge
ESD:	Rudder bulb, pre-swirl stator
VFD:	ER fans and SW cooling pumps
Lighting:	LED
Coating:	High performance
Attained EEDI:	(gas mode) 4.37
CII:	(gas mode) A-Rating

Machinery

Main engine	MAN 7G90ME-C10.5 or WinGD 8X92DF-2.0
Tier III (SCR), Dual-Fuel	
NMCR	39,000 kW @ 75 rpm
Bow Thrusters	2 x 3,500 kW
BOG Management	1 x Reliquification Plant
Fuel Preparation	ME & AE
BWTS	1 x USCG Approved
Propeller	FPP

Power Supply

Diesel Generators	2 x 4,147 kW
Tier III (SCR), Dual-Fuel	2 x 2,764 kW
Emergency Generator	1 x 350kW
Cold Ironing System (AMP)	Fixed Type, PS & STB
Power	440Vac, 3ph
Lighting	230Vac, 1ph

Gas Fuel Consumption

At design draft, 16 kn:	
Service, no reefers	267 DGC (t/day)
Service, all reefers	374 DGC (t/day)
Service, 50% reefers	326 DGC (t/day)

Oil Fuel Consumption

At design draft, 16 kn:	
Service, no reefers	87 DFC (t/day)
Service, all reefers	122 DFC (t/day)
Service, 50% reefers	106 DFC (t/day)

Complement

Crew	31 P + 6 Suez

Cargo Loading

Hatch covers:	Steel pontoon type
	90 t/20 ft & 200 t/40 ft & mixed stowage 275 t/stack
Cargo hold:	270 t/20 ft & 336 t/40 ft
IMDG Cargo:	Hold. No 1/2 & upper deck

Container Capacities

Containers intake IMO visibility guidance	ISO 8'6" high
On deck	9,234 TEU
In Hold	6,430 TEU
TOTAL	15,664 TEU
Rows max. in holds/on hatches	19 / 21 Rows
Tiers max. in holds/on hatches	11 / 11 Tiers
Lashing bridge on deck	3 tiers + 2 MM
Max. Reefer Container Plugs	
On deck (4.5 kW/plug)	1,200 FEU
In holds (6.0 kW/plug)	600 FEU
Total	1,800 FEU

Homogeneous loading:
10 t/TEU / 14 t/TEU: 13,900 / 11,686
(based on VCG as 45% of 8'6", 100% bunkering)
Hull Strength as 20% over IACS

Navigation Equipment

1 - Auto Pilot, 2 - Gyro Compass, 2 - ECDIS + conning ,
3 - Radar Plant (ARPA, ECDIS), 1 - Echo Sounder,
2 - Speed Log, 2 - DGPS, 1 - VDR, 1 - AIS, 1 - LRIT, 1 - SSAS,
1 - GMDSS A3, 3 - VHF, 2 - INMARSAT C,
1 - CCTV (16 cameras), 2 - VSAT, 1 - FB system, 1 - LTE

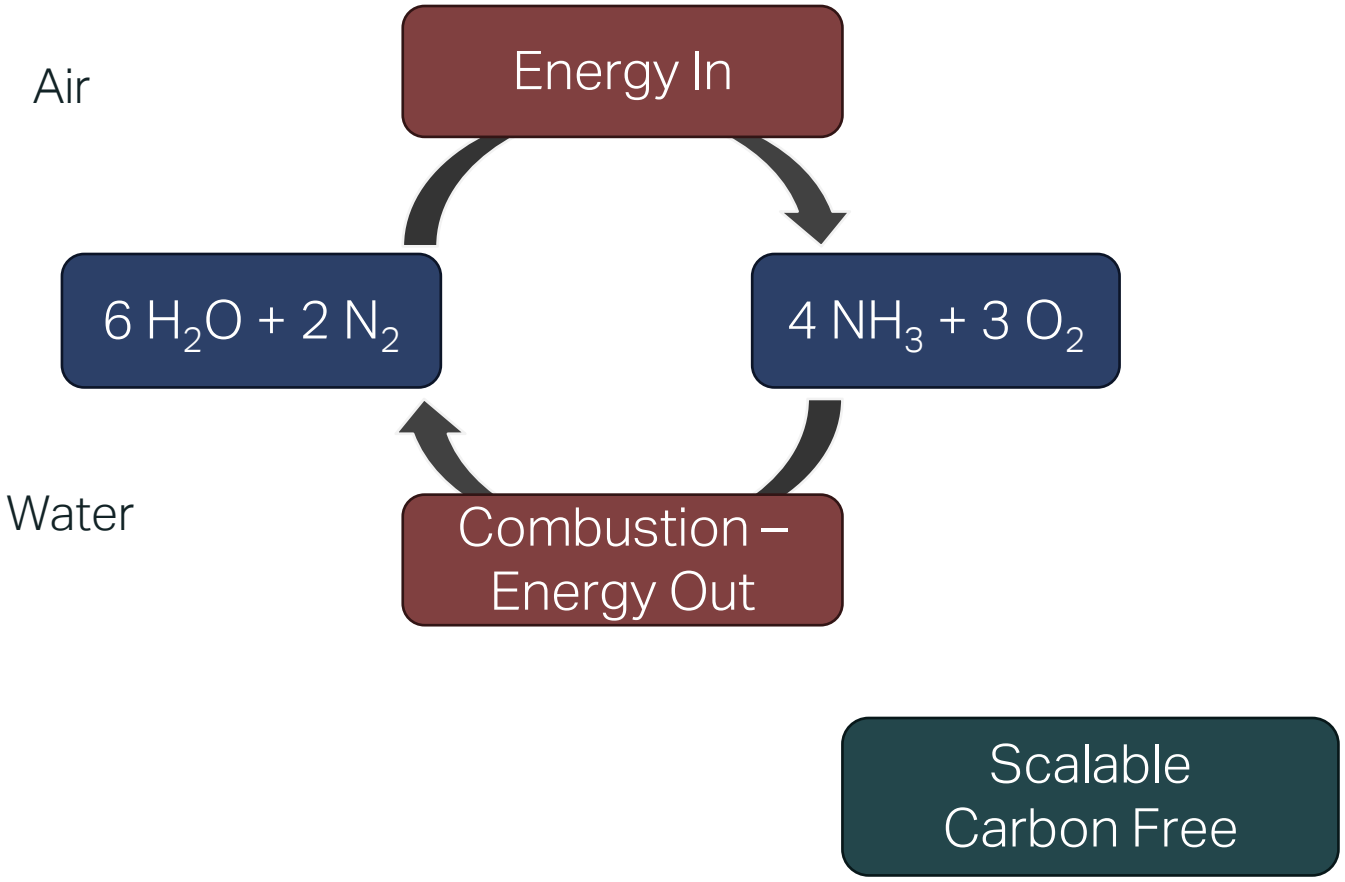
FS3788
28.3.2023

All values are approximate.

FORESHIP

Requirements

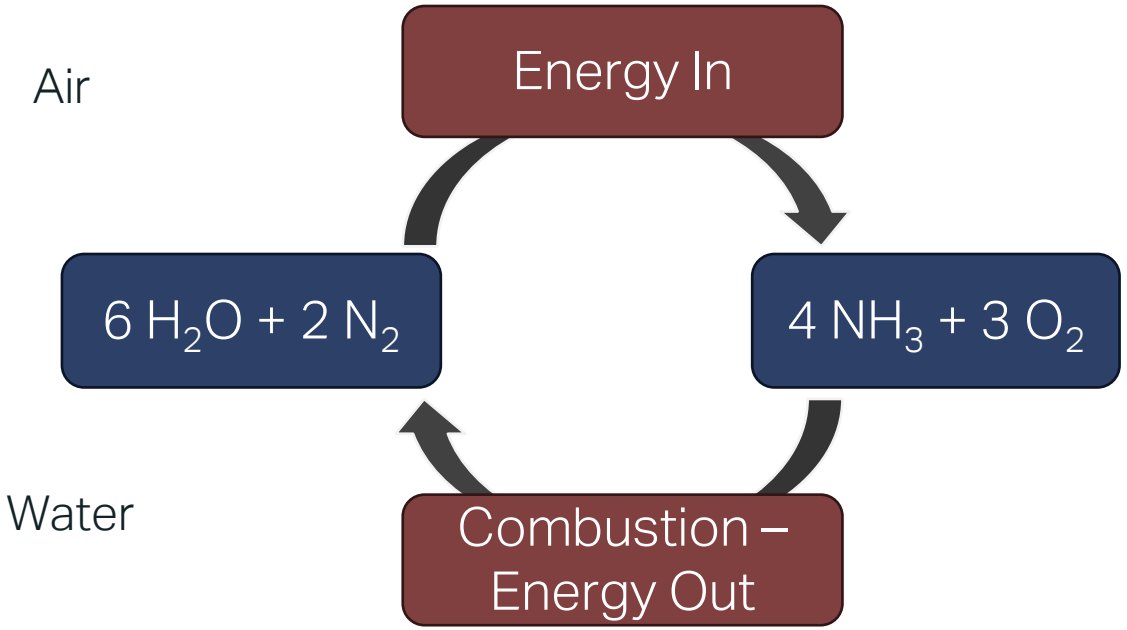
- Fuel: Ammonia



Scalable
Carbon Free

Requirements

- **Fuel:** Ammonia
- **Size:** 15kTEU



Low energy density
Refrigerated
Toxic

Scalable
Carbon Free

Large Deep Sea Vessels

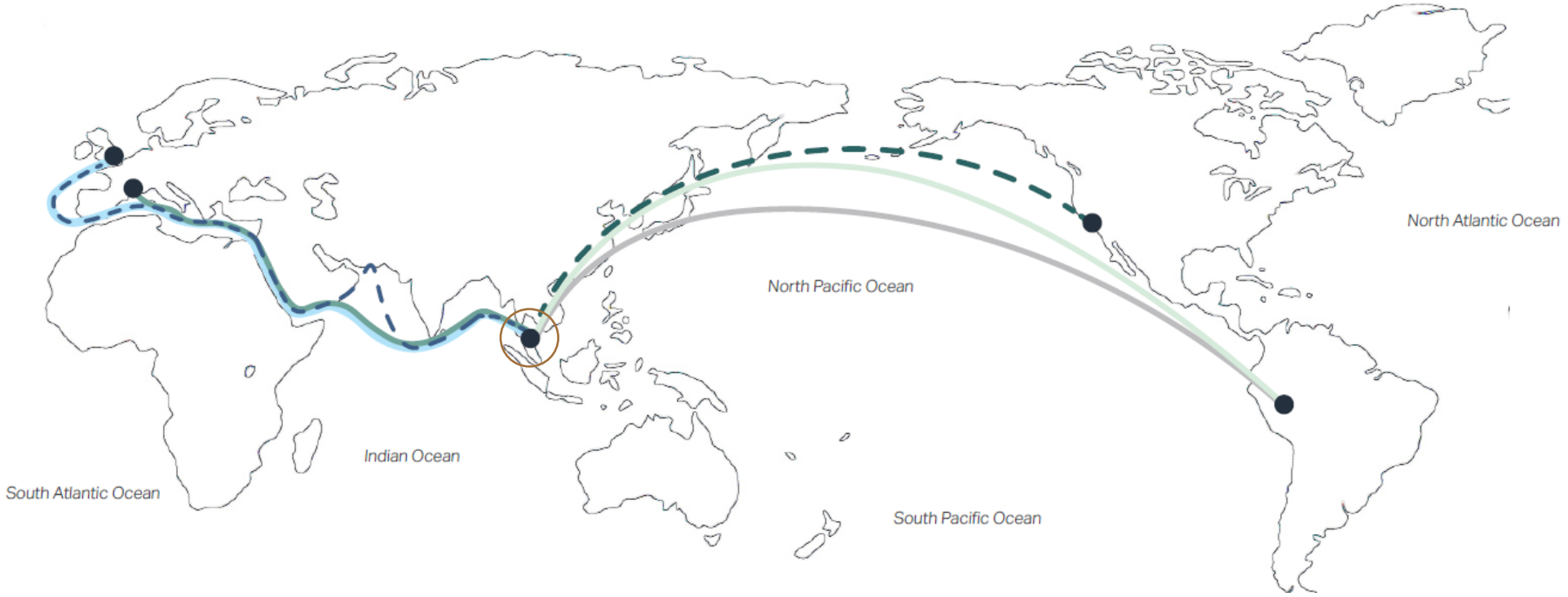
Requirements

- **Fuel:** Ammonia
- **Size:** 15kTEU
- Accommodation: Two island design
- Fuel Tank: Fuel tanks below accommodation
- Length: 350m
- Cargo; Reefer Slots; Operational Profile: 8t/TEU, 10t/TEU, 12t/TEU; 1500plugs; 14kn to 16kn

Requirements

- Trading Route:
  - Transpacific
  - Asia to Europe
- Endurance: 18,500NM

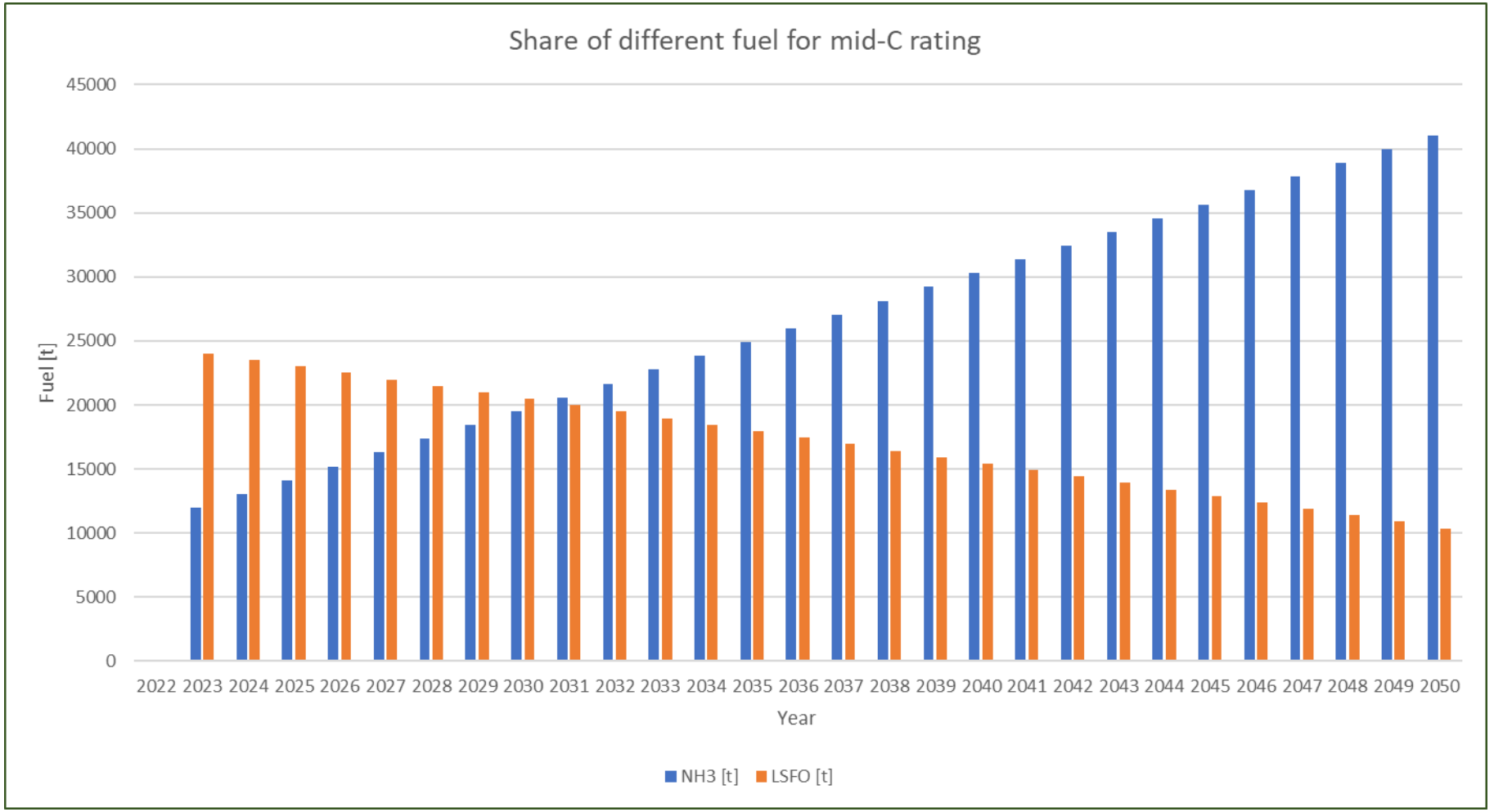
SABRE: Singapore ammonia bunkering feasibility study



Route	Name	One-way (nm) + 10% margin	Roundtrip (nm) + 10% margin
1	Asia to Mediterranean	7, 758	15,516
2	Asia to Northern Europe	9,327	18,654
3	Asia to Northern Europe + Middle East	11,234	22,468
4	Transpacific	8,831	17,662
5	Transpacific + North and South America	14,549	29,097
6	Asia to South America	13,986	27,972

Regulation – CII

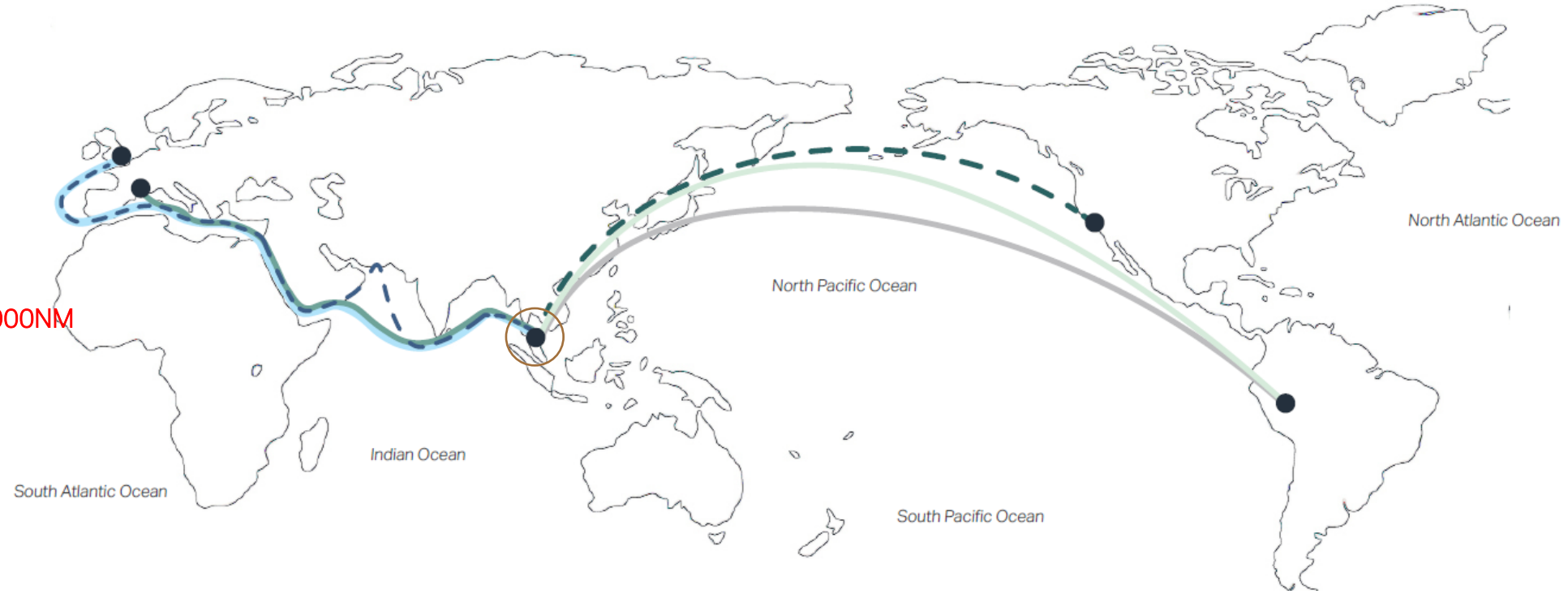
- CII Prediction:
  - Ratio of LSFO which can be consumed to maintain a Cat C: DWT180,500t, annual distance 84,000nm
  - Assuming 2% criteria reduction year on year



Requirements

SABRE: Singapore ammonia bunkering feasibility study

- Trading Route:
  - Transpacific
  - Asia to Europe
- Endurance: 18,500NM; 12,000NM
- Tank Volume: 11,500m^3



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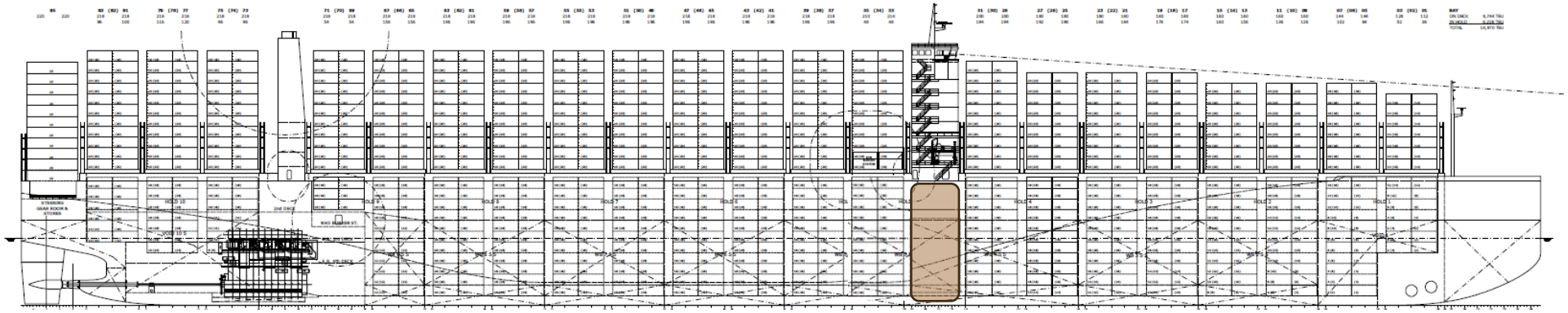
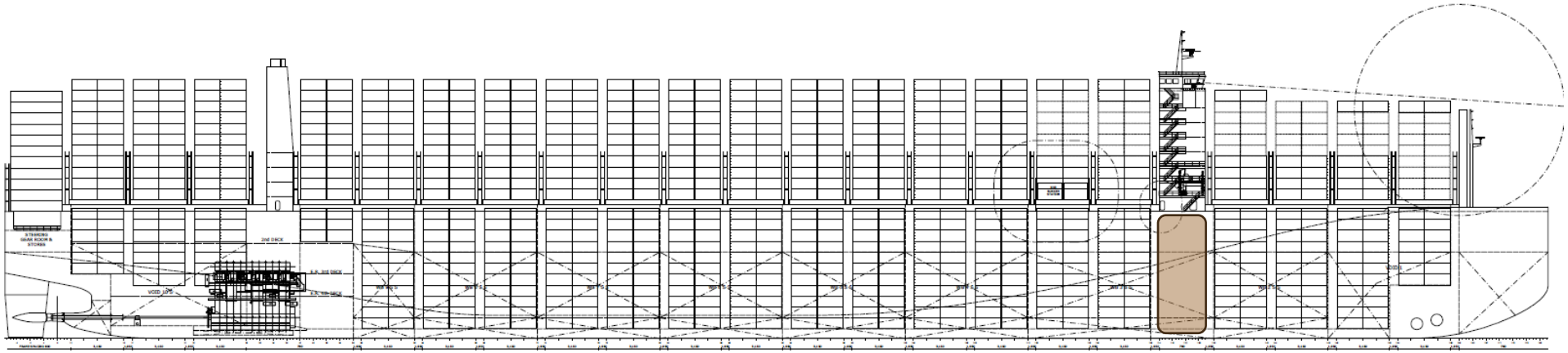
Optimisation

- Optimisation: Hull form optimised based on slot cost (t/day/TEU)
- Beam: 53m
- Cb: 0.72
- Accommodation Position:

Reduced on deck loadability



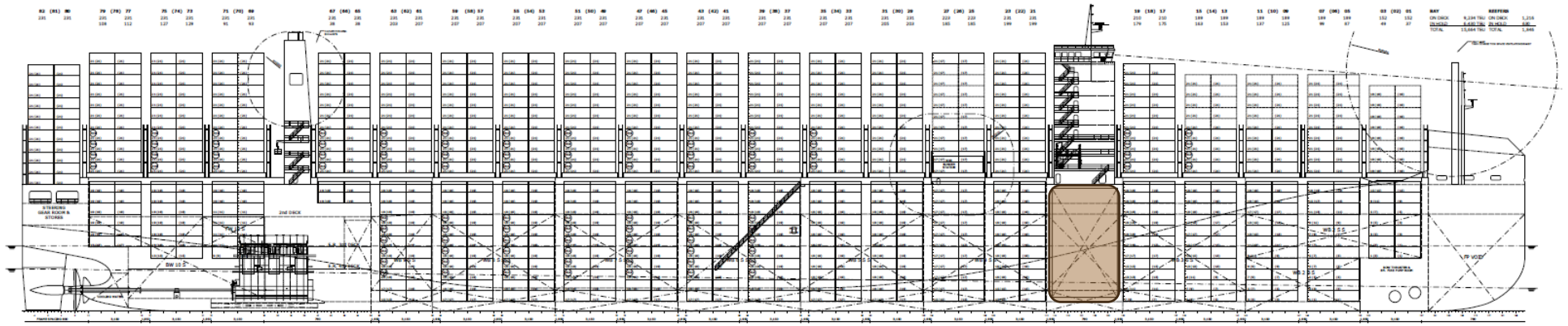


Insufficient tank capacity

Optimisation

- **Optimisation:** Hull form optimised based on slot cost (t/day/TEU)
- **Beam:** 53m
- **Cb:** 0.72
- **Accommodation Position:**

Just Perfect



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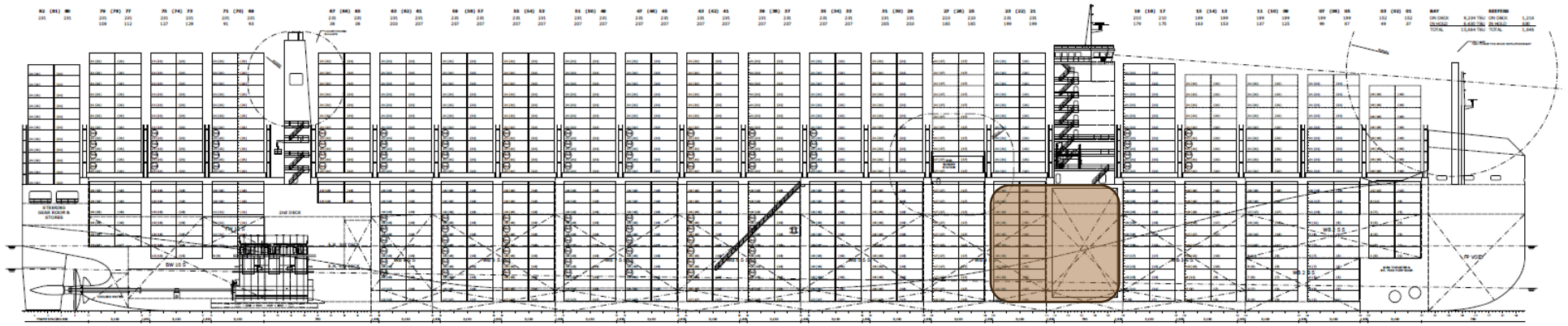


AIP

Tasks – T2402022/T2401822/T2410772/T2425296
Approval in Principle for Ammonia-Fueled 15k TEU Containership
Flag: N/A

Attention: Mr. Seb Brindley, SEASPAN SHIP MANAGEMENT LTD. (WCN: (761553)

The documents shown in the attached list are reviewed in accordance with the applicable requirements of the following:

- ABS Rules for Building and Classing Marine Vessels 2023
- ABS Requirements for Ammonia Fuelled Vessels 2022
- IGF Code 2017

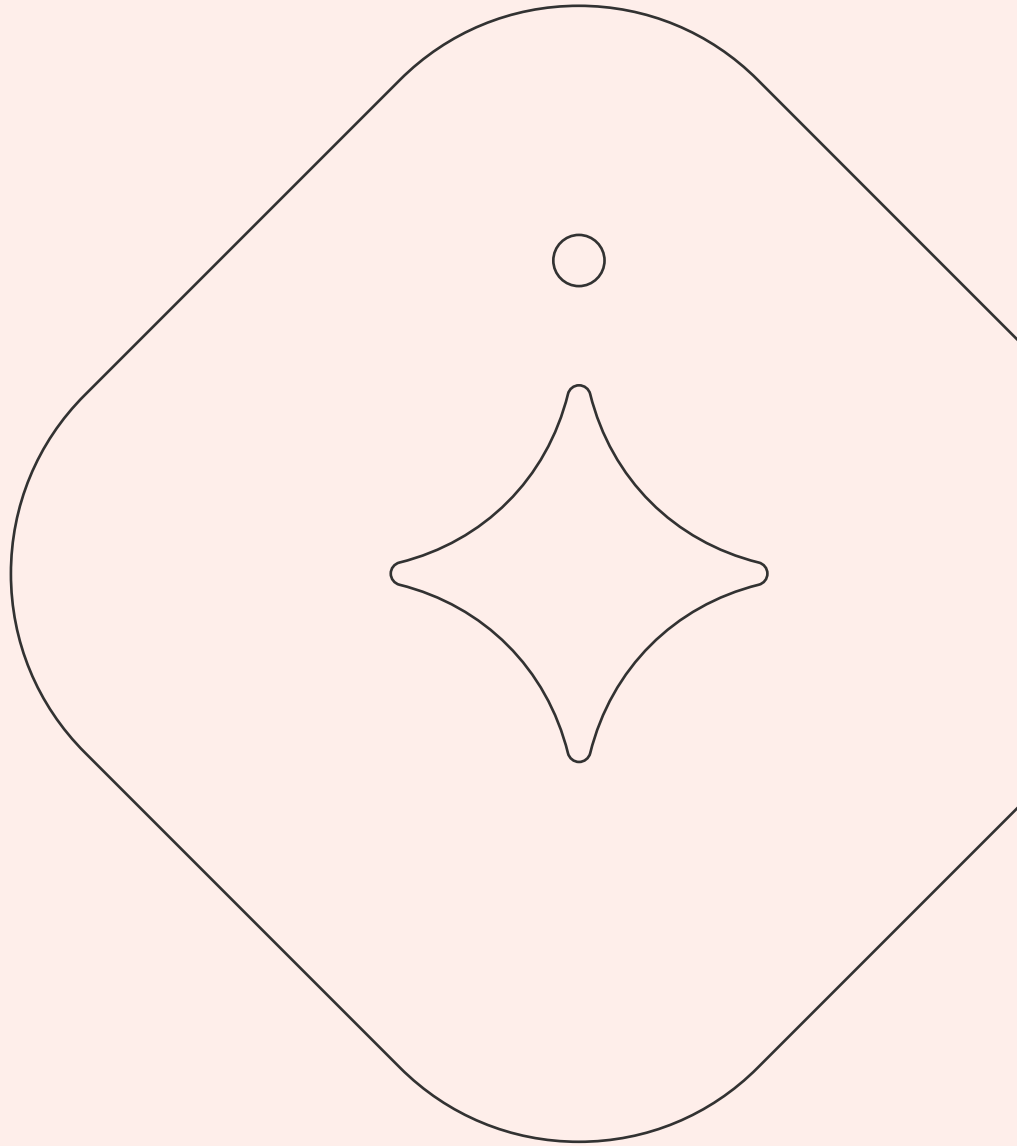
Please note our review is based on the following conditions:

1. The subject design review in the context of an “Approval in Principle” has been undertaken with the purpose of investigating the feasibility of the conceptual design and identifying any major deficiencies that would prove problematic or show-stoppers in a full ABS review of the design for classification of the subject vessel.
2. The proposed design concept in principle is acceptable.
3. Insofar as ABS requirements for classification are concerned, the arrangements and details as shown have been reviewed in accordance with the above applicable Rule requirements and appear to be satisfactory subject to comments and observations.

Concept design: Ship design process

Shaun White
Managing Director
Foreship UK Ltd.

FORESHIP



Scope

Ship Theory

- Hull Form Development
- Speed/Power Predictions
- Damage Control & Stability
- General Arrangement Development
- Machinery Concepts

Design

- Risk Assessment
- Rules & Regulations
- Profiles & Arrangements
- 3D Models
- 3D Renderings

Impact Assessment

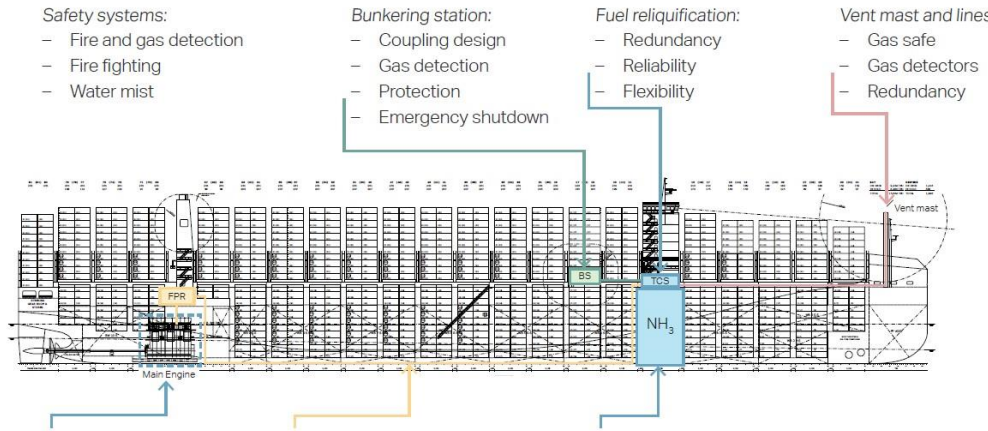
- Endurance Calculations
- Fuel Consumption Calculations
- Emissions Calculations
- CII, EEDI Calculations
- TRL and Market Availability

Risk Assessment

Methodology

- Qualitative HAZID Risk Assessment
- Improve the conceptual design safety
- Risk identification, evaluation, composition
- Share industry experience and knowledge
- Basis for further research, risk analysis
- HAZID Nodes
  - Bunker Station(s) Arrangement
  - Fuel Storage Tank
  - Fuel System/Preparation
  - Fuel Reliquification / Vapor Handling
  - Vent / Vent Lines / Vent Mast
  - Fire and gas detection, Firefighting, Water Mist

HAZID Nodes and Focus Areas



Summary of HAZID Risk Ratings

- 5x5 Matrix Categories
  - Asset
  - Environment
  - Community/Government/Media/Reputation
  - Injury and Disease
- No Extreme, Intolerable Risks
- High Risks – Additional Control Required
- Medium Risks – No Additional Control
- Low Risks – No Action Required

Category				Consequence				
Asset				No shutdown, costs less than $10,000 to repair	No shutdown, costs less than $100,000 to repair	Operations shutdown, loss of day rate for 1-7 days and/or repair costs of up to $1,000,000	Operations shutdown, loss of day rate for 7-28 days and/or repair costs of up to $10,000,000	Operations shutdown, loss of day rate for more than 28 days and/or repair more than $10,000,000
Environment				No lasting effect. Low level impacts on biological or physical environment. Limited damage to minimal area of low significance.	Minor effects on biological or physical environment. Minor short-term damage to small area of limited significance.	Moderate effects on biological or physical environment but not affecting ecosystem function. Moderate short-medium term widespread impacts e.g., oil spill causing impacts on shoreline.	Serious environmental effects with some impairment of ecosystem function e.g., displacement of species. Relatively widespread medium-long term impacts.	Very serious effects with impairment of ecosystem function. Long term widespread effects on significant environment e.g., unique habitat, national park.
Community/Government/Media/Reputation				Public concern restricted to local complaints. Ongoing scrutiny/ attention from regulator.	Minor, adverse local public or media attention and complaints. Significant hardship from regulator. Reputation is adversely affected with a small number of site focused people.	Attention from media and/ or heightened concern by local community. Criticism by NGOs. Significant difficulties in gaining approvals. Environmental credentials moderately affected.	Significant adverse national media/ public/ NGO attention. May lose license to operate or not gain approval. Environment/ management credentials are significantly tarnished.	Serious public or media outcry (international coverage). Damaging NGO campaign. License to operate threatened. Reputation severely tarnished. Share price may be affected.
Injury and disease				Low level short-term subjective inconvenience or symptoms. No measurable physical effects. No medical treatment required.	Objective but reversible disability/impairment and/ or medical treatment. Injuries requiring hospitalisation.	Moderate irreversible disability or impairment (<30%) to one or more persons.	Single fatality and/ or severe irreversible disability or impairment (>30%) to one or more persons.	Short- or long-term health effects leading to multiple fatalities, or significant irreversible health effects to >50 persons.
				Low	Minor	Moderate	Major	Critical
				1	2	3	4	5
Likelihood	Occurs 1 or more times a year	Almost certain	E	0	0	0	0	0
	Occurs once every 1-10 years	Likely	D	1	1	1	0	0
	Occurs once every 10 - 100 years	Possible	C	17	11	9	0	0
	Occurs once every 100 - 1,000 years	Unlikely	B	17	19	23	12	0
	Occurs once every 1,000 - 10,000 years	Rare	A	1	13	26	13	4
Action key	Low			No action is required, unless change in circumstances				
	Moderate			No additional controls are required, monitoring is required to ensure no changes in circumstances				
	High			Risk is high and additional control is required to manage risk				
	Extreme			Intolerable risk, mitigation is required				

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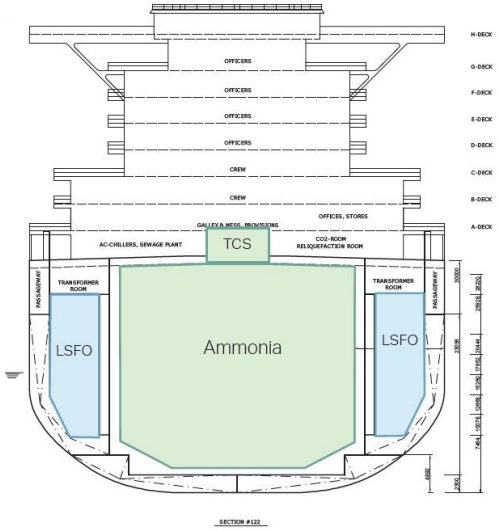
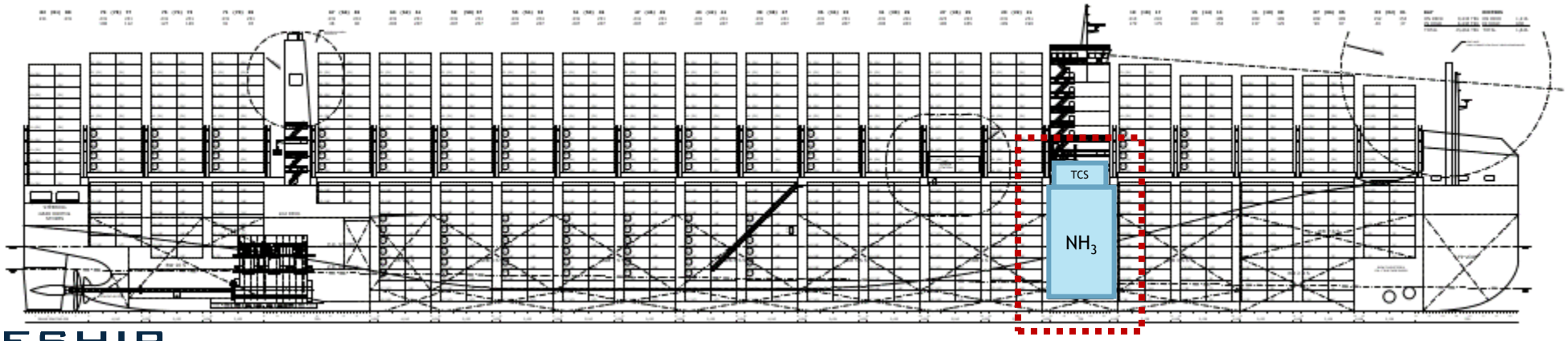
Ammonia Storage

Location	• Under Accommodation Block
Tank Size	• 11,500m³
Tank Type	• IMO Type B
Tank Width	• Maintain B/5 Prescriptive Requirement
Tank Connection	• Directly above Tank
BOG Management	• 1xreliquification + connection to boiler





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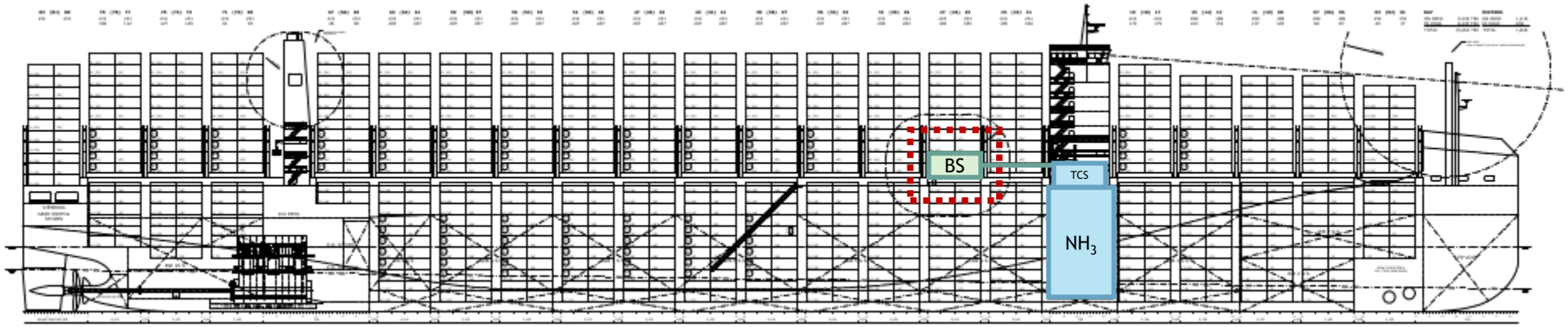
Ammonia Bunker Station

Location	• Two bays aft of accommodation - loose 1 row in hold due to width of station
Arrangement	• Semi enclosed • Reinforced Deckhead Structure - Protected from dropped containers
Connections and Capacity	• Max 3off 8” hose connections and 1off 8” vapor return line • Bunker capacity: 2000m^3/hr. (subject to future safety review)
Safety	• Safety shower, eye wash, fixed fire and gas detection, drain tank and system, ESD system, CCTV system, means of escape, mechanical ventilation, water curtain system



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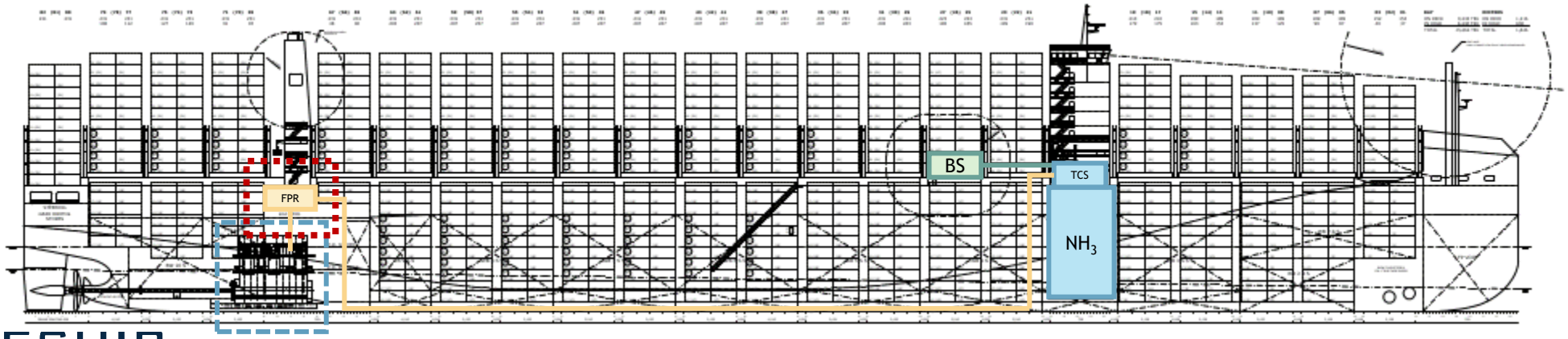
Fuel Preparation Room

Equipment	• Fuel pumps, fuel valve trains, heat exchangers, filters, knock-out drums, and ammonia release mitigation systems
Location	• Above Main Engine Room • Reduce route length of high-pressure ammonia piping
Arrangement	• Split - Main Engine FPR, Auxiliary Engine FPR • Enable easy and fast escape
Safety	• Safety shower, eye wash, fixed fire and gas detection, fixed drip trays, ESD system, audible and visual alarms, dedicated mechanical ventilation, oxygen level detection and alarms, CCTV system



FORESHIP

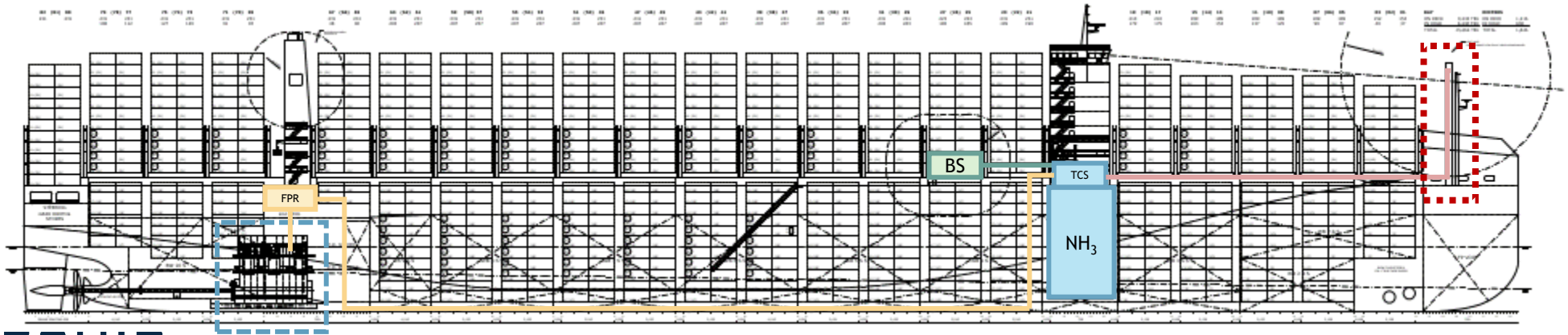
Venting

Location

- The vent mast is located 25 m from the accommodation air intakes
- Two independent vent lines are provided, one routed port side and one routed starboard side
- Vent lines are routed under the hatch covers to protect from dropped objects
- The vent mast will also be provided with fixed ammonia gas detection

Venting only for emergency scenarios

Vapour returned to bunker vessel during bunkering



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Further Design

Reduce risks associated with leakages or releases when storing ammonia fully refrigerated.

Optimization of ammonia storage tank location, volumes, and the vessel's endurance to minimize container slot loss and risk of tank penetrations.

Definition of hazardous zones, separate spaces for ammonia-related equipment, and multiple access/egress points.

Challenges
Ammonia leakage and release scenarios to minimize risks to crew onboard.
Ammonia emission profiles, pilot fuel requirements, and safety implications
Ammonia Onboard systems development and proper and safe design integration.
Ammonia risk mitigation measures and incorporation into the concept design
Ammonia fuel consumption and associated operational expenses through enhanced energy efficiency measures

Industry perspectives

Regulations

René Laursen

Director, Fuels & Technology

American Bureau of Shipping (ABS)

Engines

Nikolaos Kourtidis

Two-Stroke Promotion & Customer Support

MAN Energy Solutions

Bunkering

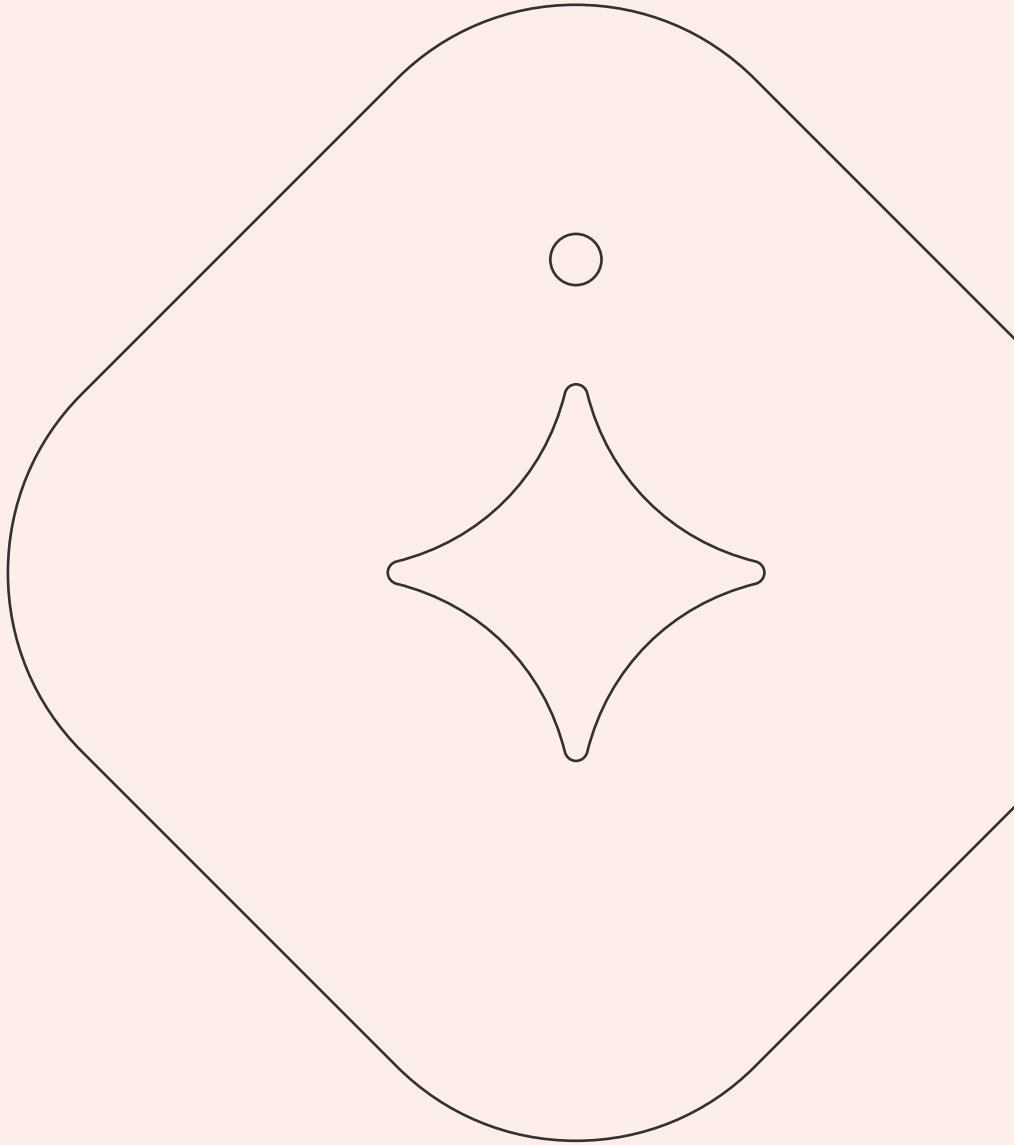
Prakash Chandra

Director

Fleet Management Limited

Ammonia-related regulations

René Laursen
Director, Fuels & Technology
American Bureau of Shipping (ABS)



Current Rules and Regulations

- IGF Code
  - Adopted June 2015 – MSC.391(95)
  - Entry Into Force 1 January 2017
  - IGF Code does not apply to gas carriers using cargoes or other low flashpoint fuels as fuel
  - **Detailed requirements for natural gas only**
  - **Other low flashpoint fuels by 'Alternative Design' under 2.3**
    - Equivalence by SOLAS regulation II-1/55 and MSC.1/Circ.1212 – risk assessment
    - Methyl/ethyl requirements approved by MSC102 in Nov 2020
  - IGF Code incorporated under 5C-13 of ABS MVR

2.3 Alternative design

2.3.1 This Code contains functional requirements for all appliances and arrangements related to the usage of low-flashpoint fuels.

2.3.2 Fuels, appliances and arrangements of low-flashpoint fuel systems may either:

.1 deviate from those set out in this Code, or

.2 be designed for use of a fuel not specifically addressed in this Code.

Such fuels, appliances and arrangements can be used provided that these meet the intent of the goal and functional requirements concerned and provide an equivalent level of safety of the relevant chapters.

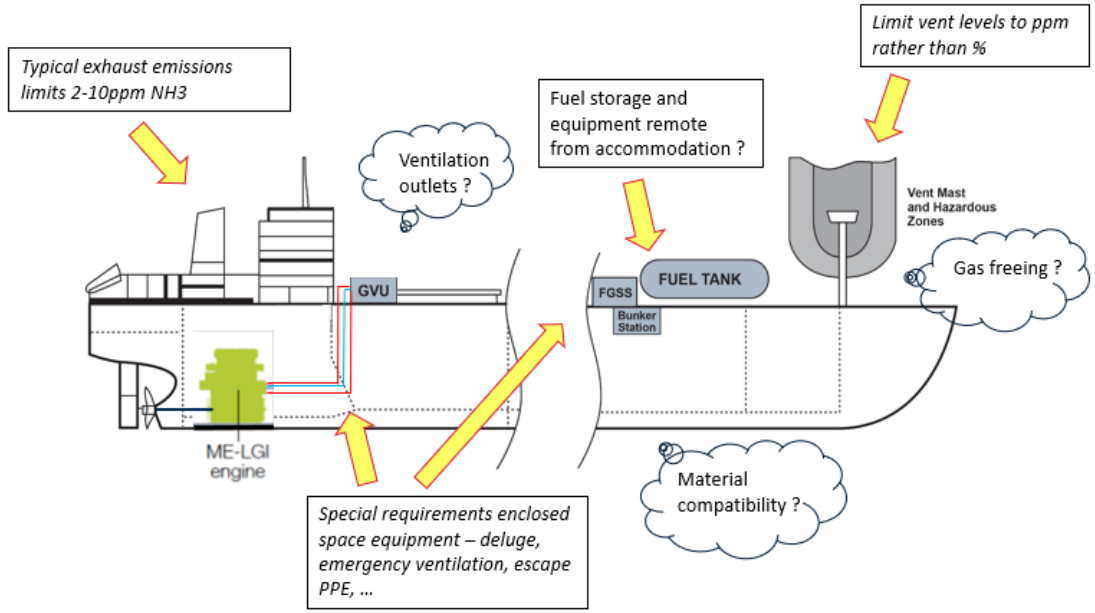
2.3.3 The equivalence of the alternative design shall be demonstrated as specified in SOLAS regulation II-1/55 and approved by the Administration. However, the Administration shall not allow operational methods or procedures to be applied as an alternative to a particular fitting, material, appliance, apparatus, item of equipment, or type thereof which is prescribed by this Code.

Source: IMO IGF Code

ABS

Specific Concerns with Ammonia Fuel

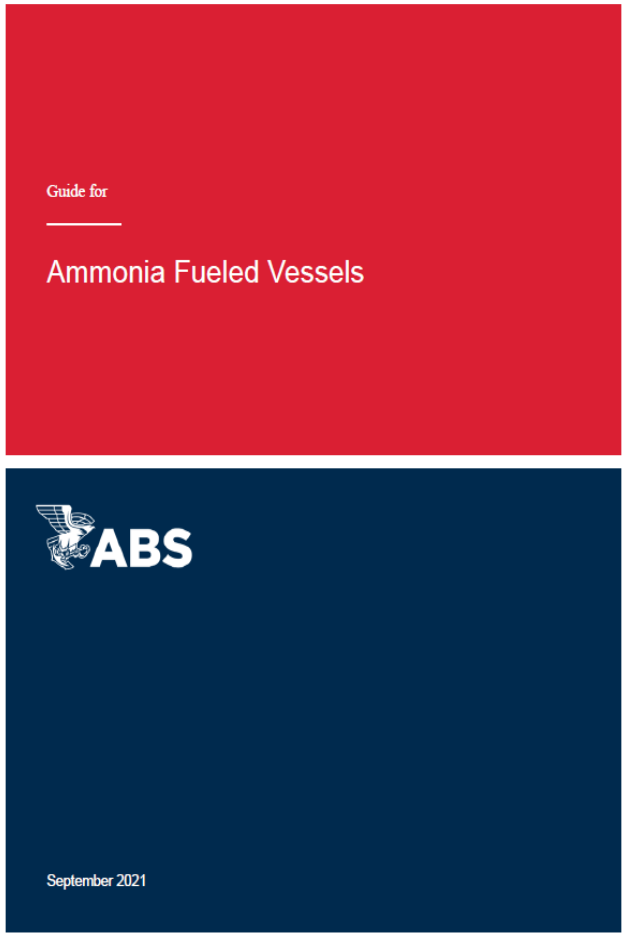
- Toxicity/Strong odor
  - Restricting venting to ppm levels rather than LEL
  - Treatment of fuel returns and blowdowns
  - Location of vent outlets
  - In case of type A tank – vent from secondary barrier to be specially considered
  - Leaks/release in confined spaces
- Gas freeing operations
  - At quay with N_2 from shoreside (unless IGG available onboard)
  - Mobile Incinerators?
- N_2O Emissions. Potent GHG, presently unregulated
  - Prototype engine testing required to understand the issue



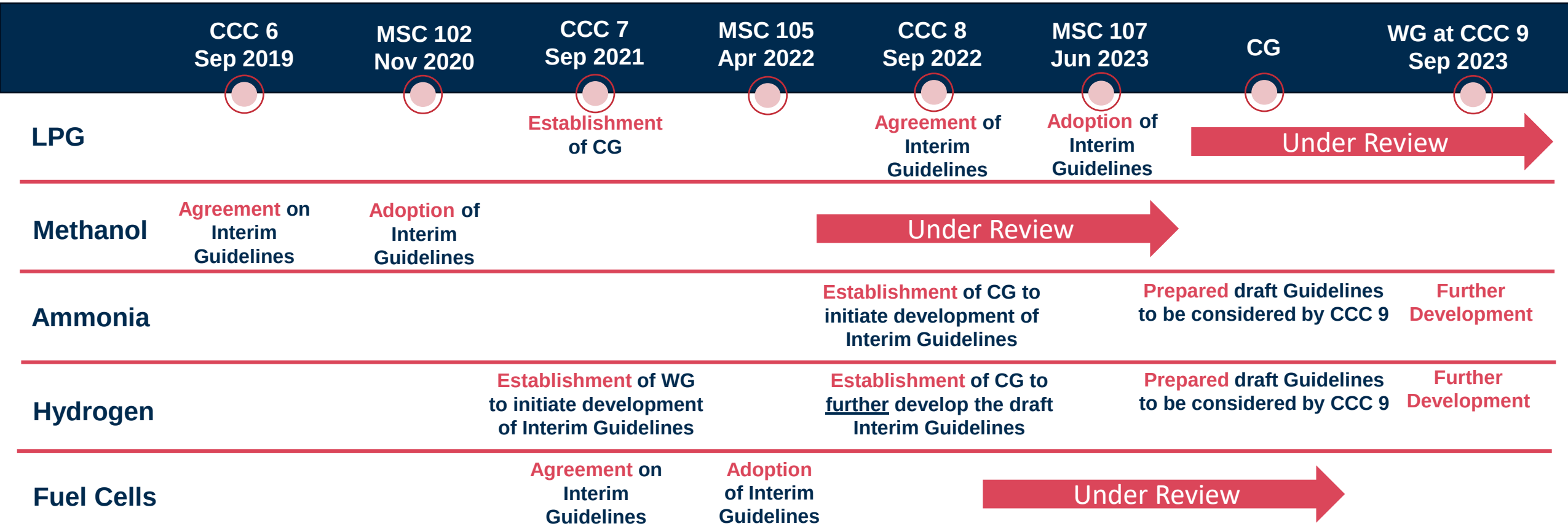
- Corrosive nature → use of some metals to be avoided in FGSS
- Gas-freeing of FGSS and engine prior maintenance

ABS *Guide for Ammonia Fueled Vessels*

- Introduces additional requirements to mitigate hazards of storage, distribution, treatment, bunkering and burning of ammonia
  - Applicable to all n/c and conversions, including those less than 500GT
  - Fuel supply, storage, bunkering and consumers to be designed to **prevent venting under all normal operating conditions**
  - **PPE** to be provided, including air sets, EEBD and eyewash/decontamination showers
  - IGF Code ESD machinery space not accepted
  - Machinery spaces to be **ACC**, **ACCU** or **ABCU**
  - IGC Code **5C-8-17/12.2-12.8 material requirements** for carbon manganese or nickel steels for containment and piping

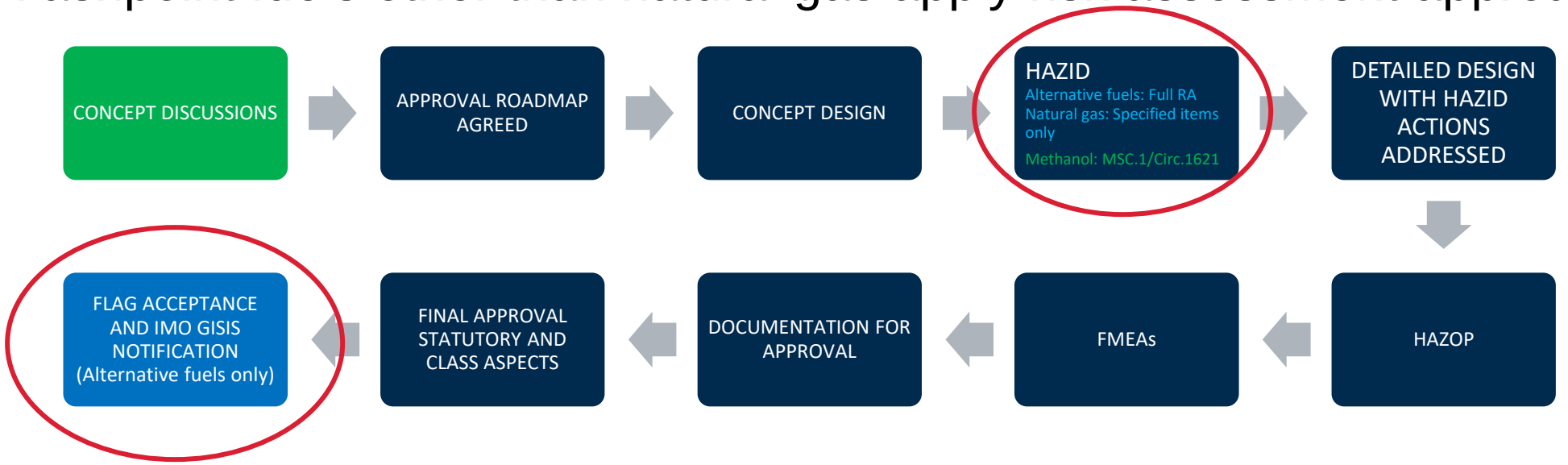


Regulatory Framework for Alternative Fuels



IGF Code Roadmap for Approval

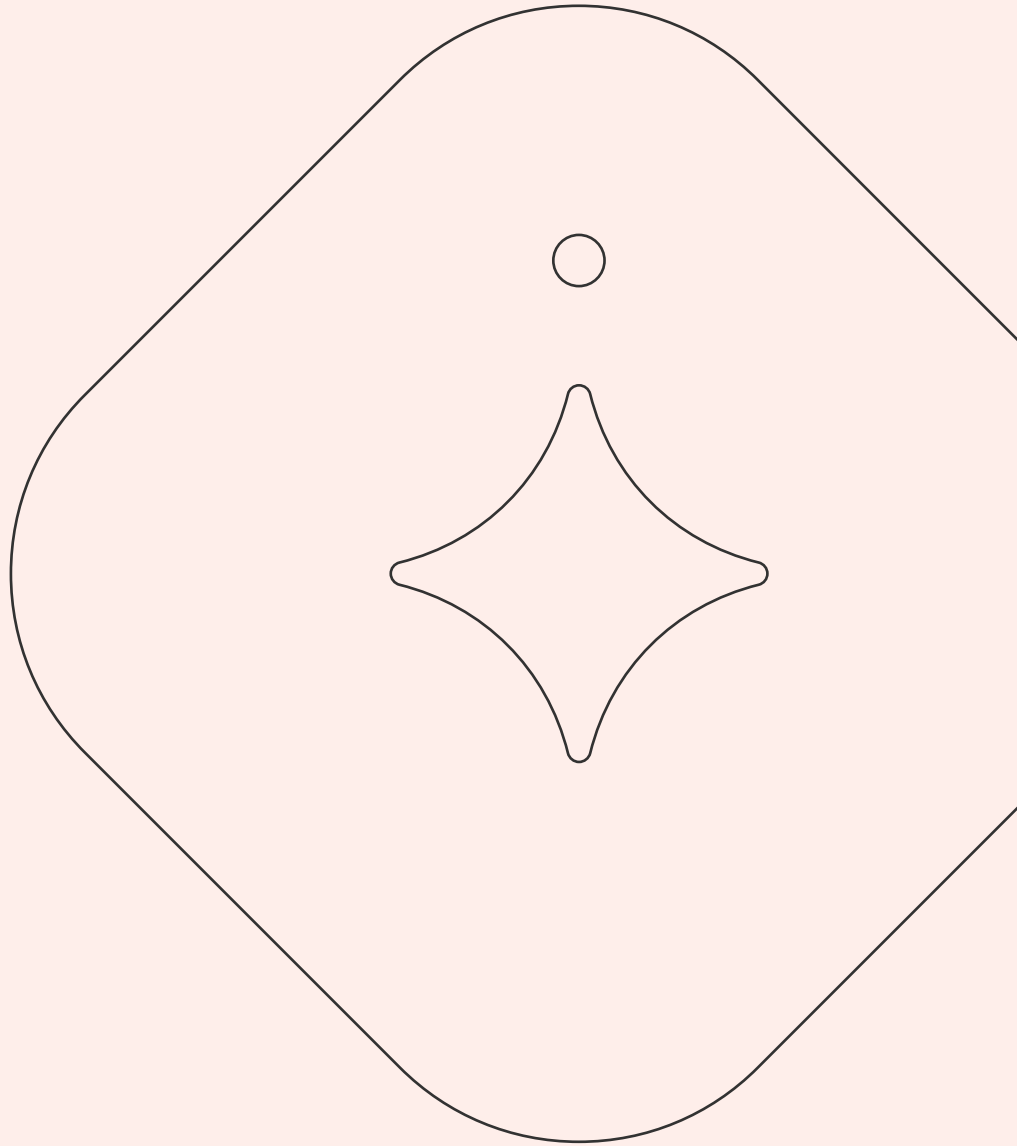
- Agree with flag and Class the approval roadmap to address safety and environmental aspects
  - Class compliance – Rules
  - Statutory safety – IGF Code
  - Statutory environmental – MARPOL Annex VI SOx, NOx, EEDI
  - Flag specific and operational area
- Low flashpoint fuels other than natural gas apply risk assessment approach



Ammonia dual-fuel engine development and key findings

Nikolaos Kourtidis
Two-Stroke Promotion & Customer Support
MAN Energy Solutions

MAN Energy Solutions
Future in the making

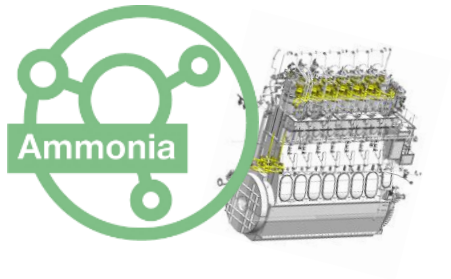


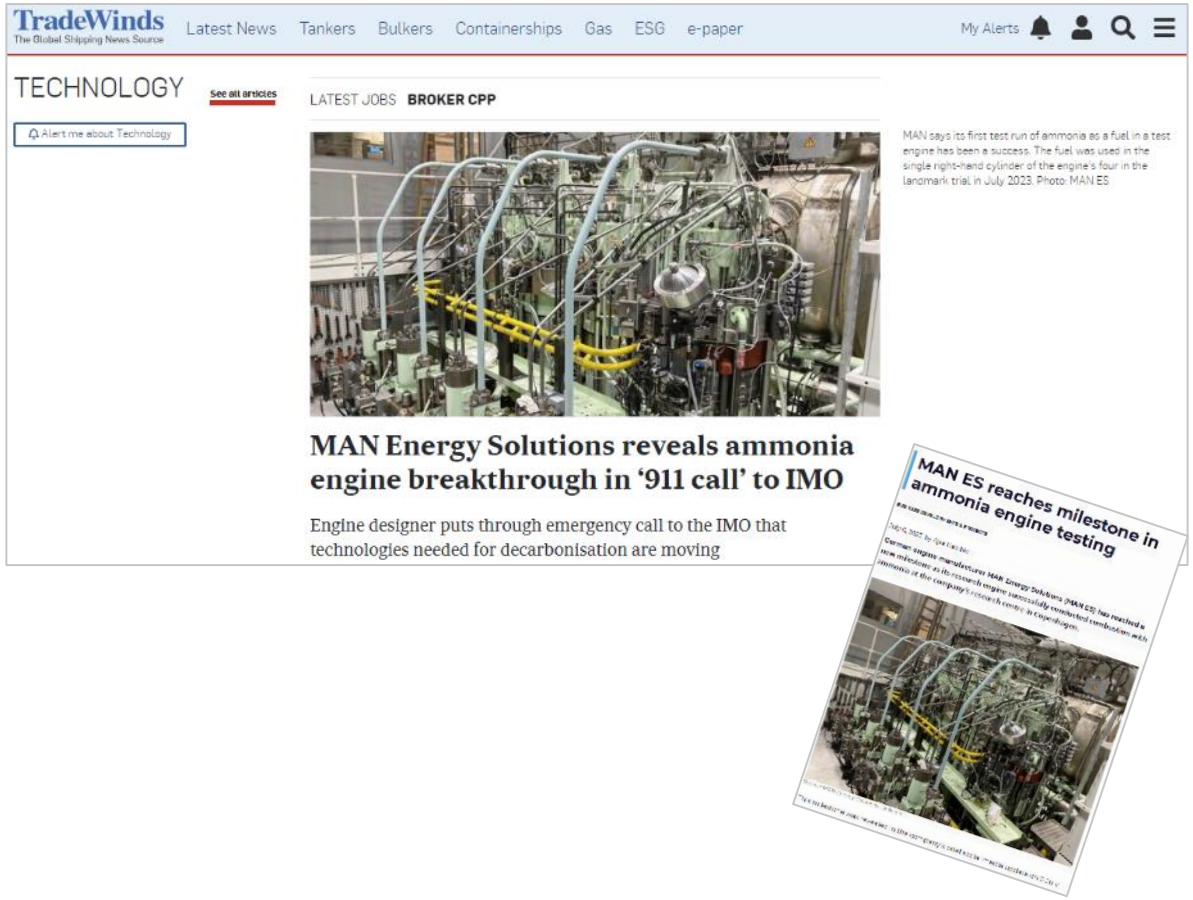
Proudly announcing a new era in shipping!

MAN ES has recently announced that a test was **successfully conducted** with the first two-stroke ammonia engine combustion tests taking place in July 2023, in our Research Centre Copenhagen.

As per August we have managed to run 100% load on ammonia.

Combustion of ammonia constitutes a major milestone in the ammonia engine development!

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LATEST JOBS **BROKER CPP**

MAN says its first test run of ammonia as a fuel in a test engine has been a success. The fuel was used in the single right-hand cylinder of the engine's four in the landmark trial in July 2023. Photo: MAN ES

MAN Energy Solutions reveals ammonia engine breakthrough in '911 call' to IMO

Engine designer puts through emergency call to the IMO that technologies needed for decarbonisation are moving

MAN ES reaches milestone in ammonia engine testing

Two-stroke ammonia engine main development timeline

R&D development
Copenhagen

First engine delivery
2024

Positive seagoing experience

Full sales release

Unique and breakthrough R&D progress

72,000 R&D man hours completed ~ 48 R&D man years

- 37 patent applications filled around ammonia engine development.
- 4 additional applications in the filling process.
- 6 patents granted.

2020

- First 2 patent applications for ammonia engine filled.
- 2 patents registered.

2021

- 7 patents applications filled.
- 4 patents registered.

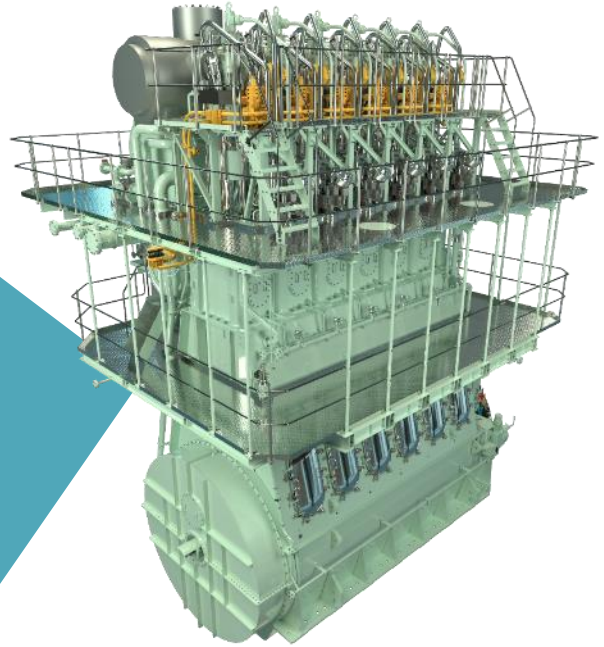
2022

- 15 additional patent applications filled.

2023

- 9 more patent applications are filled.
- 4 more patent applications are pending filling (Q2**).**

2024



Well-engineered and unique MAN B&W ammonia engine.

Two-stroke ammonia engine development schedule

2019

Pre-study

- ✓ NH_3 combustibility investigation.

2020

Project kick-off

- ✓ 4T50ME-X test engine received as platform for the ammonia engine development.
- ✓ HAZID workshop on engine concept.
- ✓ Combustion chamber 1st evaluation.

2021

Engine concept R&D

- ✓ Engine basic concept defined based on R&D and simulations.
- ✓ Ammonia fuel supply & auxiliary systems specified.

2022

Engine combustion and emission

- ✓ Ammonia fuel supply & auxiliary systems established in Research Centre Copenhagen (RCC).
- ✓ 1 cylinder engine and auxiliary system preparation at RCC.

2023

Full scale engine test

- ✓ 1st bunkering of ammonia at RCC.
- ✓ 1st engine confirmation at RCC
- Full scale design work.
- Specification of emission after-treatment.

2024

1st engine delivery to yard

- Full scale engine test at RCC evaluated for 1st commercial design.
- 1st ammonia fueled engine delivered to yard.

Ammonia engine development

The LGI combustion principle

The MAN B&W ammonia engine design philosophy

“Ammonia mode”:

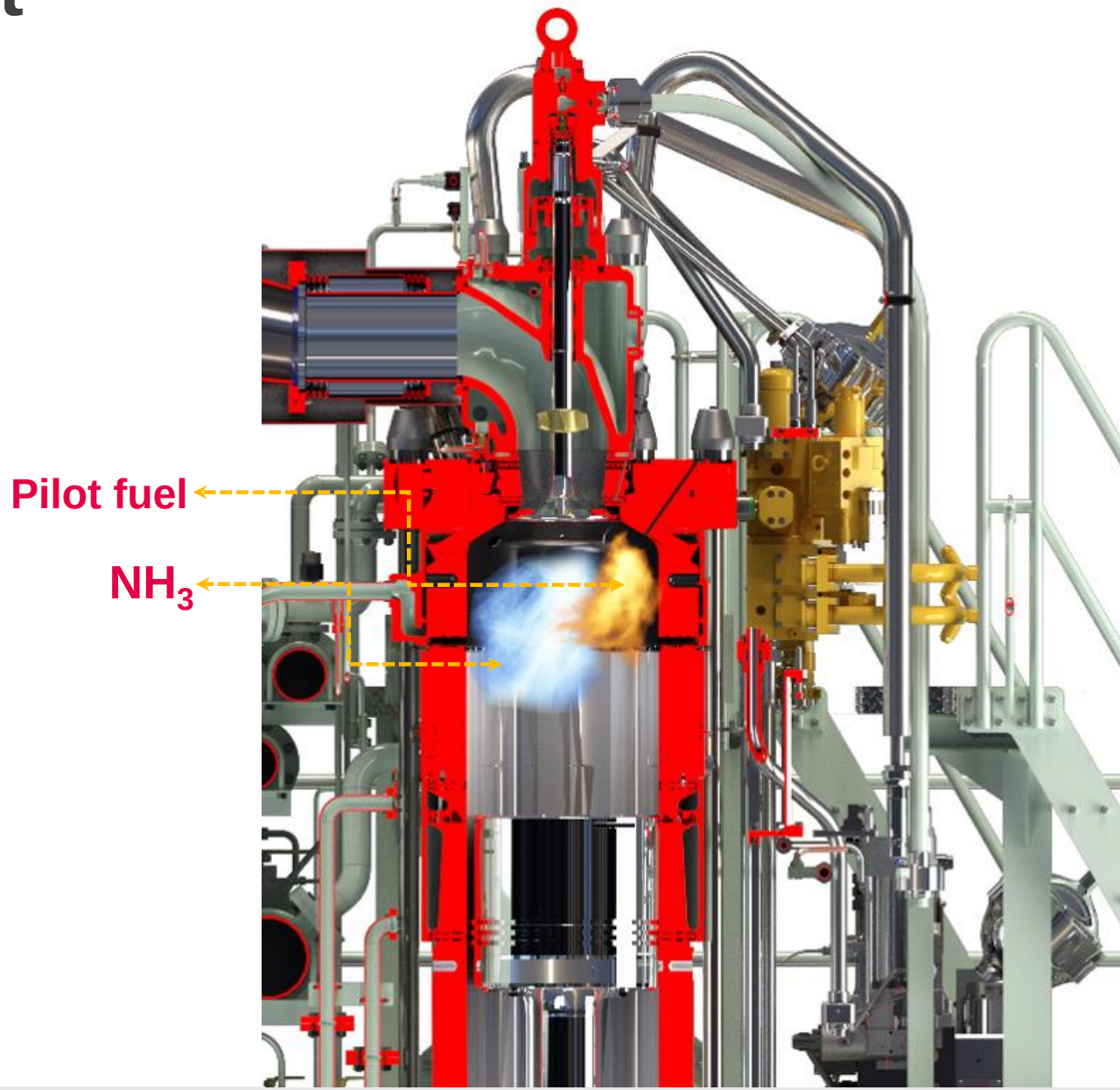
- Small pilot flame needed to start ammonia combustion.
- Initial tests conducted with 10-15% pilot as a first step → R&D target is around 5% pilot oil at 100% load for L1-rated engines.
- We target for same heat rate as “fuel oil mode”

“Fuel oil mode”:

- We target identical performance as a conventionally fueled diesel engine.

N_2O is a very potent GHG with GWP of 298. It will also be accounted for in FUELEU regulation.

- Nitrous oxide (N_2O) will be removed by engine tuning.
- Alternatively a reactor if required (pending).



Status at Research Centre Copenhagen

Auxiliary systems, ammonia tank and other facilities, June 2023 status

Installation of the auxiliaries

– Installations around the engine, such as bunkering and supply, are now well into operation

– Installations has been inspected by third party and tested with ammonia and are performing to our satisfaction

– Testing of the installation is a crucial part of the ammonia engine development project

Ammonia catch system

Ammonia bunkering facility with sprinkler system

Ammonia bunkering operation

Ammonia service tank

FVT and double wall ventilation absorber

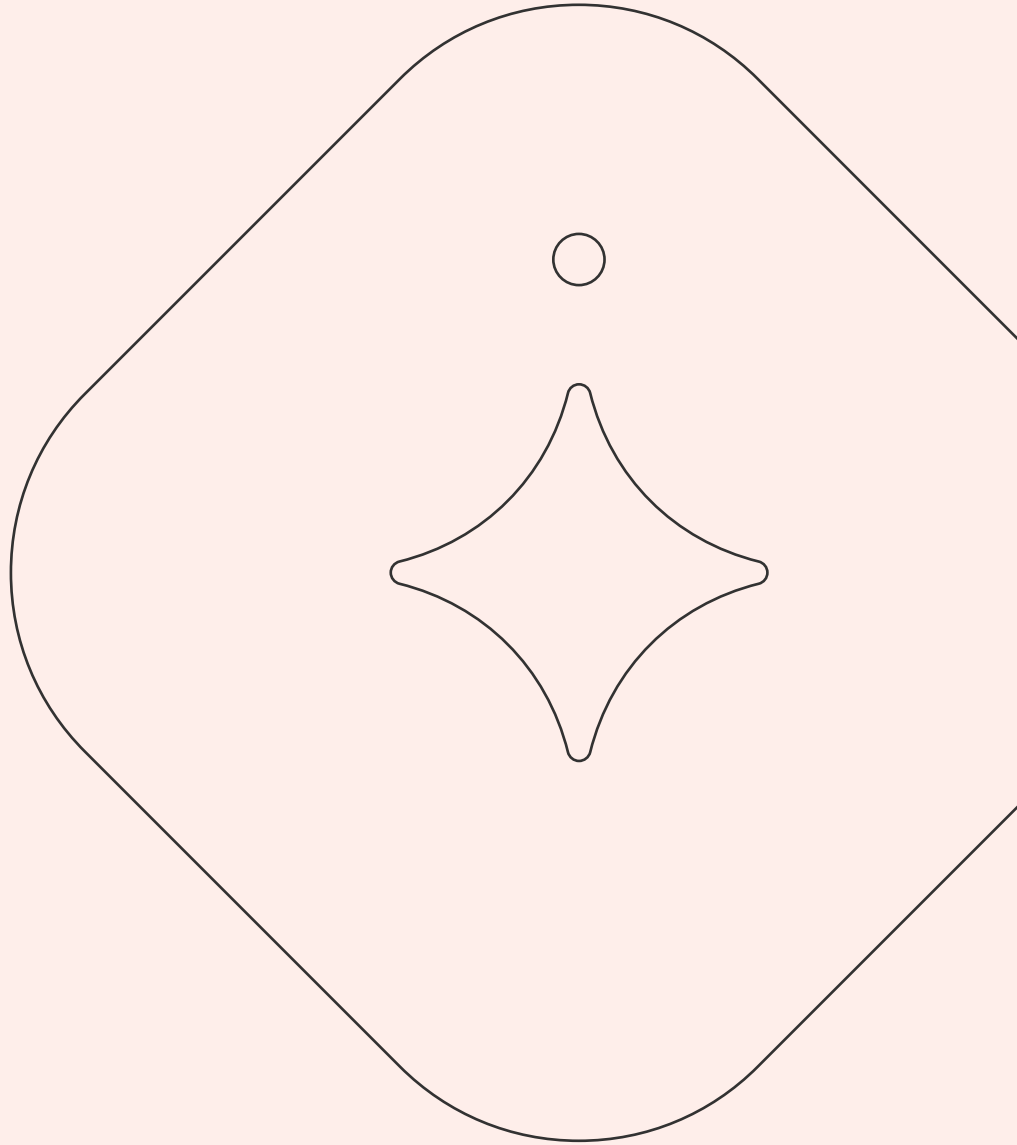
Disclaimer

All data provided in this document is non-binding.
This data serves informational purposes only and is especially not guaranteed in any way.
Depending on the subsequent specific individual projects, the relevant data may be subject to changes and will be assessed and determined individually for each project. This will depend on the particular characteristics of each individual project, especially specific site and operational conditions.

Challenges and solutions of bunkering ammonia

Prakash Chandra
Director
Fleet Management Limited

Fleet Management Limited
A Caravel Group Company



Bunkering of Cryogenic fuel to non cryogenic vessels

- A well tested bunkering solution is already available to handle cryogenic fuel
- Similar bunkering arrangement is being considered for Ammonia
- Ammonia bunkering vessel (ABV) will be equipped with loading arm similar to LNG bunkering vessel
- There will be also a bunkering manifold provided with three liquid line and two vapor line on both side of bunkering vessel
- Ammonia fuelled vessel (AFV) will have bunker manifold about midship, with one or more liquid line and a vapor return line. The number of manifolds will be dependent on size of ship and its bunkering tank
- ESDS and other safeties will be similar

- SO WHAT ARE THE CHALLENGES WHICH ARE DIFFERENT ?

CHALLENGES FOR AMMONIA BUNKERING AND SOLUTIONS

❖ What is different?

- Ammonia is toxic; A LEAK creates immediate threat to the habitat including marine environment
- Due to low volumetric energy density of ammonia AFV will have larger requirement of bunker
- To meet with the demand of AFV, ABV will be of large size
- Handling of a large bunkering vessel will require additional features to meet with local port regulations for a bunkering vessel
- To bunker larger quantity of ammonia fuel in similar time, like LNG powered vessels, larger hoses/multiple hoses and higher pumping rate will be required

CHALLENGES FOR AMMONIA BUNKERING AND SOLUTIONS

❖ What is different?

- Similarly to handle larger hoses and high pumping requirement, the bunkering equipment needs to be redesigned
- Spill control equipment needs to be designed to handle larger volumes and toxic gas
- Special protection for manifold and bunkering equipment against leak
- Ventilation arrangement and main vent mast will be different
- Study for the dispersion of ammonia will need to be done
- ZERO EMISSION FOR ALL PROCESS

CHALLENGES FOR AMMONIA BUNKERING AND SOLUTIONS

- What are the potential solutions?

- The weak link is the connection point, which are manifold and hoses

- The manifold :
- Manifold needs to be designed focusing on protection against spill and spread of ammonia vapors
- The vessels may have a semi enclosed manifold with provision of water mist and air extraction system

CHALLENGES FOR AMMONIA BUNKERING AND SOLUTIONS

❖ What are the potential solutions?

- The manifold flange will have protection shield to prevent spray in case of leak
- The manifold will be arranged with large spill tray to contain the leak in spill tray
- There will be a separate storage tank to contain ammonia mixed water in tanks
- Manifold will be equipped with water mist system to prevent spread of vapors
- NO EMISSION TO ATMOSPHERE – Purge tank

CHALLENGES FOR AMMONIA BUNKERING AND SOLUTIONS

- What are the potential solutions?
- The hose :

CONSTRUCTION

Inner wire	Stainless steel 316
Outer cover	Polyamide White color
Lining	Polyamide fabrics
Outer wire	Stainless steel 316

CHARACTERISTIC

Max. elongation	10% on proof pressure
Min. burst pressure	5x working pressure (Safety factor 5:1)
Temperature range	-50℃ to +50℃ / -105℃ to +50℃ (For liquid ethylene)
Electrical resistance	≤2.5 Ohm/m for under 50mm (2″) ≤1.0 Ohm/m for over 50mm (2″)

CHALLENGES FOR AMMONIA BUNKERING AND SOLUTIONS

❖ What are the solutions?

- The hose could be 8” inch cryogenic hose
- The max permitted flow rate is about 1250m3/hr for ammonia. For safety reasons during bunkering, the max rate permitted should be 1000m3/hrs
- To meet the time requirement of large container vessels, up to 3 hoses can be used at a time with one vapor return line
- The hose should be tested to ISO 1402 standard, like any other cryogenic hose. The hose should be tested against crushing damage and undergo a burst test. These hoses are made of several layers of multi plastic and are very difficult to leak
- The additional protection is the insulation sleeve which can be attached to the hose to prevent spray, and the leak can be collected back to the drip tray

Insulation protection sleeve for jet spray

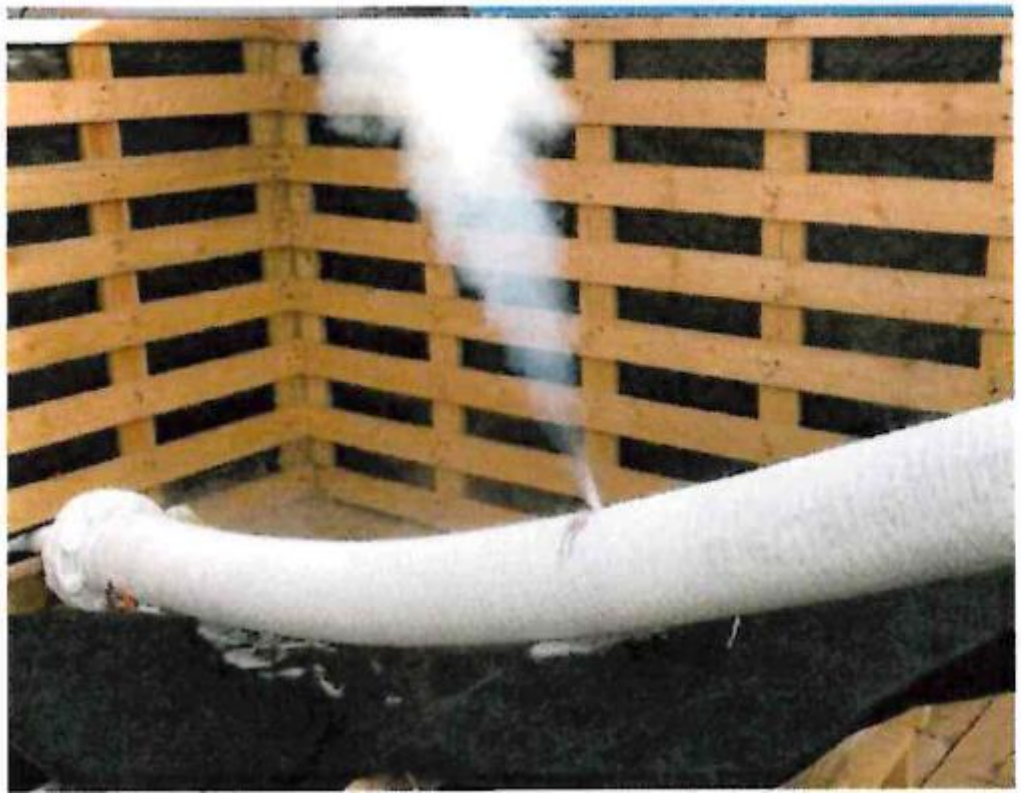
Sleeve details:

- **Cryojacket LNG Protection sleeve**
- **PA6.6 Polyamide fabric black, water repellent.**
- **Protection sleeve LNG and other cryogenic liquids down to 196°C**
- **Equipped with min 40mm Velcro for easy connection and disconnection (1"-2" might be smaller)**
- **Lengths up to 30,00 meter, longer available on customer request**
- **Possibility to add eyeleds on both ends**

By Trellborg

Insulation protection sleeve for jet spray

Made of Polyamide woven fabric codurablack 0.5 mm thick and hold in position by wilcro tape



By Trellborg

It will leak before it bursts….

A video of a burst test

Specification n of hose used for test :

Hose type : Multi-LNG White
Size : 8”
Sample length : 3,00 mtr
Temperature : LN2 / -196°C
Design P : 21 bar
Min Burst P : 105 bar
Actual Burst P : 178 bar

Very important is it proves leak before burst!!

By Trellborg

It will leak before it bursts

By Trellborg

Bunkering solutions – The loading arm

Has been redesigned to handle 3 hoses of 8”

QCDC – Quick release and no leak

STUDY OF AMMONIA DISPERSION

Ship-to-ship bunkering

Ship-to-ship bunkering with cargo handling (SIMOPS)

Truck-to-ship bunkering

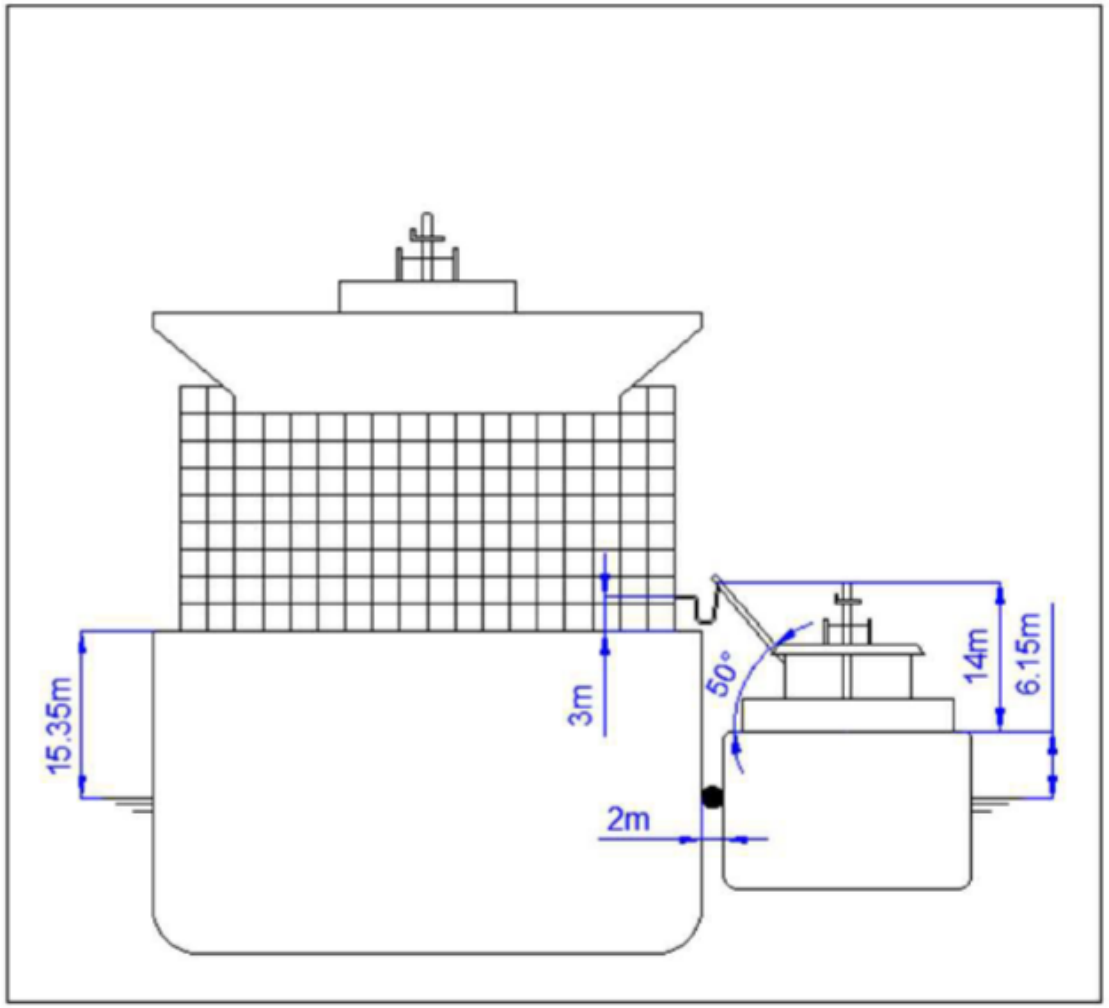
No.	Bunkering Mode	Supply Vessel/Facility	Receiving Vessel	CFD simulation of Ammonia Dispersion		
				Wind Direction	Dispersion Time	Concentration

1	Ship to ship	NH3 carrier	Container ship	• Dispersion of liquid ammonia
				  • Wind blows from bunker vessel to receiving vessel
				  • Wind blows from receiving vessel to bunker vessel
				• Dispersion of ammonia vapor
				  • Wind blows from bunker vessel to receiving vessel
				  • Wind blows from receiving vessel to bunker vessel
					• 30s
					• 60s
					• 2 min
					• 5 min
						• 30ppm (AEGL 1)
						• 160ppm (AEGL 2)
						• 1100ppm (AEGL 3)

2	Ship to ship	NH3 carrier	LPG carrier			
3	Ship to ship	NH3 carrier	Bulk carrier			
4	SIMOPS	NH3 carrier	Container ship			
5	Truck to ship	Truck (ISO tank)	Tugboat			
6	FSU to ship	FSU	Container ship			

STUDY OF AMMONIA DISPERSION

Category	Parameter	Value
Ammonia release	Release location	Ammonia bunker hose connection at the receiving vessel
	Isolation time	1 min for fully automated blocking system
	Total release volume	26.29 m^3
	Release elevation	Around 18.35 m above water line
	Orifice size	203 mm
	Jet direction	Vertical up
	Liquid fraction	0.999805 (Simulated by PHAST software)
Weather condition	Temperature	30°C (Singapore ambient temp.)
	Relative humidity	85%
	Solar radiation	1 kW/m^2
	Wind speed	3 m/s



seaspan

Mærsk Mc-Kinney Møller Center
for Zero Carbon Shipping

Classification Society:
ABS

Ship Designer:
FORESHIP

On today's webinar panel

Seb Brindley

Senior Naval Architect

Seaspan Corporation (MMMCZCS Secondee)

Shaun White

Managing Director

Foreship UK Ltd

René Laursen

Director, Fuels & Technology

American Bureau of Shipping (ABS)

Nikolaos Kourtidis

Two-Stroke Promotion & Customer Support

MAN Energy Solutions

Prakash Chandra

Director

Fleet Management Limited

Claus Rud Hansen

Senior Technology Manager

A.P. Moller-Mærsk (MMMCZCS Secondee)

Matt Dunlop

Director of Sustainability and Decarbonization

V.Group (MMMCZCS Secondee)

Thomas McKenney

Head of Ship Design

MMMCZCS

Thank you for joining!

The recording & presentations will be shared with all participants shortly.

Let's stay in touch

Visit our website www.zerocarbonshipping.com and make sure to follow us on LinkedIn to stay up to date with the latest news and events.

Mærsk Mc-Kinney Møller Center
for Zero Carbon Shipping

Related Projects

→ Nordic Green Ammonia Powered Ships
One of the first ammonia-fueled vessel designs

→ MAGPIE
Demonstrating ammonia bunkering in Rotterdam