HEXAGON

Hexagon Energy Materials Ltd

FUTURE ENERGY AND ENERGY MATERIALS

FUTURE ENERGY – BLUE AND GREEN AMMONIA END MARKETS

USE OF DECARBONISED AMMONIA AS A MARITIME SHIPPING FUEL

OVERVIEW

Maritime shipping accounts for 75% of total global freight transport activity (IEA, 2021). Generally, the maritime shipping industry has used oil as the fuel source, coupled with reciprocating diesel engines due to their operating simplicity, robustness, and fuel economy. The international shipping industry represents approximately 3% of global greenhouse gas emissions (IMO, 2021). The use of decarbonised (Blue and/or Green) Ammonia or **MAmmonia** as a shipping fuel has the potential to significantly cut carbon emissions. Ammonia does not emit Carbon Dioxide (CO_2) when burned.

THE CHEMICAL REACTION

Diesel combustion reaction:

$$4C_{12}H_{23} + 71O_2 \rightarrow 46H_20 + 48CO_2$$

Diesel + Oxygen → Water + Carbon Dioxide

Ammonia combustion reaction:

$$2NH_3 + \frac{3}{2}\,O_2 \rightarrow 3H_20 + N_2$$

Ammonia + Oxygen → Water + Nitrogen

Ammonia does not emit CO_2 when burned

NEW TECHNOLOGY ENABLING MIXED FUEL & SINGLE AMMONIA FUEL IN MARITIME ENGINES

Given (1) the demand for maritime transport is forecasted to increase amid the ongoing desire to grow the world economy and (2) greenhouse gas emission mandates set by both country and industry, billions of dollars are being invested to develop innovative maritime technology to enable the use of mixed fuel and single **MAmmonia** fuel for combustion.

Due to the low flammability of Ammonia, mixed fuel reciprocating engines are being developed using both **MAmmonia** and conventional fuels (as the pilot fuel). This type of ship is expected to reduce CO_2 emissions by 91.9% compared to conventional ships of the same type and size (MLIT, 2020).

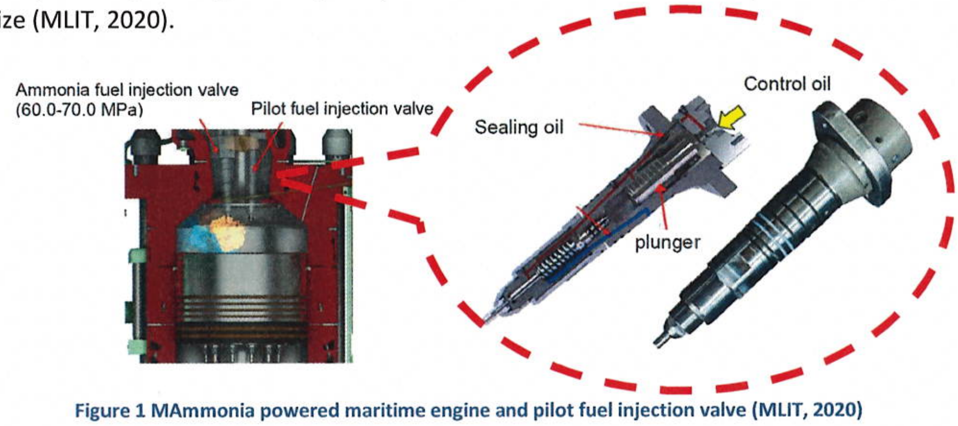

Figure 1 MAmmonia powered maritime engine and pilot fuel injection valve (MLIT, 2020)

Single **MAmmonia** fuel engines are also in development. The proposed fuel injection is similar to that planned for dual fuel engines powered by Liquid Petroleum Gas (LPG) and heavy oil. LPG, whose main component is propane or butane, can be liquefied under pressures and temperature conditions similar to those for **MAmmonia**.

Wärtsilä, a global leader in the maritime engine market, have already developed and are testing an engine with 70% **MAmmonia** at typical marine load ranges. Wärtsilä anticipates having an engine concept with single **MAmmonia** fuel by 2023 (Wärtsilä Corporation, 2021). The largest global shipbuilders are also getting in on the act, with Samsung Heavy Industries (SHI) planning to commercialise an **MAmmonia**-powered oil tanker by 2024 and both Hyundai Heavy Industries (HHI) and Korea Shipbuilding & Offshore Engineering (KSOE) designing and developing an Ammonia carrier with **MAmmonia**-fuelled propulsion (Ammonia Energy Association, 2021).

Figure 2 (L) Testing of MAmmonia as a viable fuel for shipping (Wärtsilä Corporation, 2020), (M) full scale MAmmonia fuel tests underway (Wärtsilä Corporation, 2021), (R) MAmmonia fuelled ship with bunkering infrastructure technology concept (Amon Maritime, 2021).

MAMMONIA ADVANTAGES AS A MARITIME FUEL

- No CO_2 emissions onboard using **MAmmonia**
- Storage of **MAmmonia** using existing LPG storage tank technologies – easy to store **MAmmonia** in liquid form
- **MAmmonia** easily made available for shipping – already stored & handled in 120 ports around the world
- Low production, storage, and transport costs of **MAmmonia** compared to other carbon-neutral fuels
- Existing cargo handling technologies can be used for **MAmmonia** bunkering
- **MAmmonia** already proven as a drop in fuel with diesel

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