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AMMONIA SAFETY

Ammonia effects on humans

- Ammonia is highly toxic
- Ammonia can cause acute toxication values low as 300-700 ppm
- These levels are well below the LEL limit of 15%
- Dissolves in bodily fluids and cause irritation.
- Exposure to liquid ammonia can cause cold burns.
- High concentrations may cause chemical burns.
- Not a carcinogenic agent.



DEMO 2000 – NH3 Demonstration project at Stord



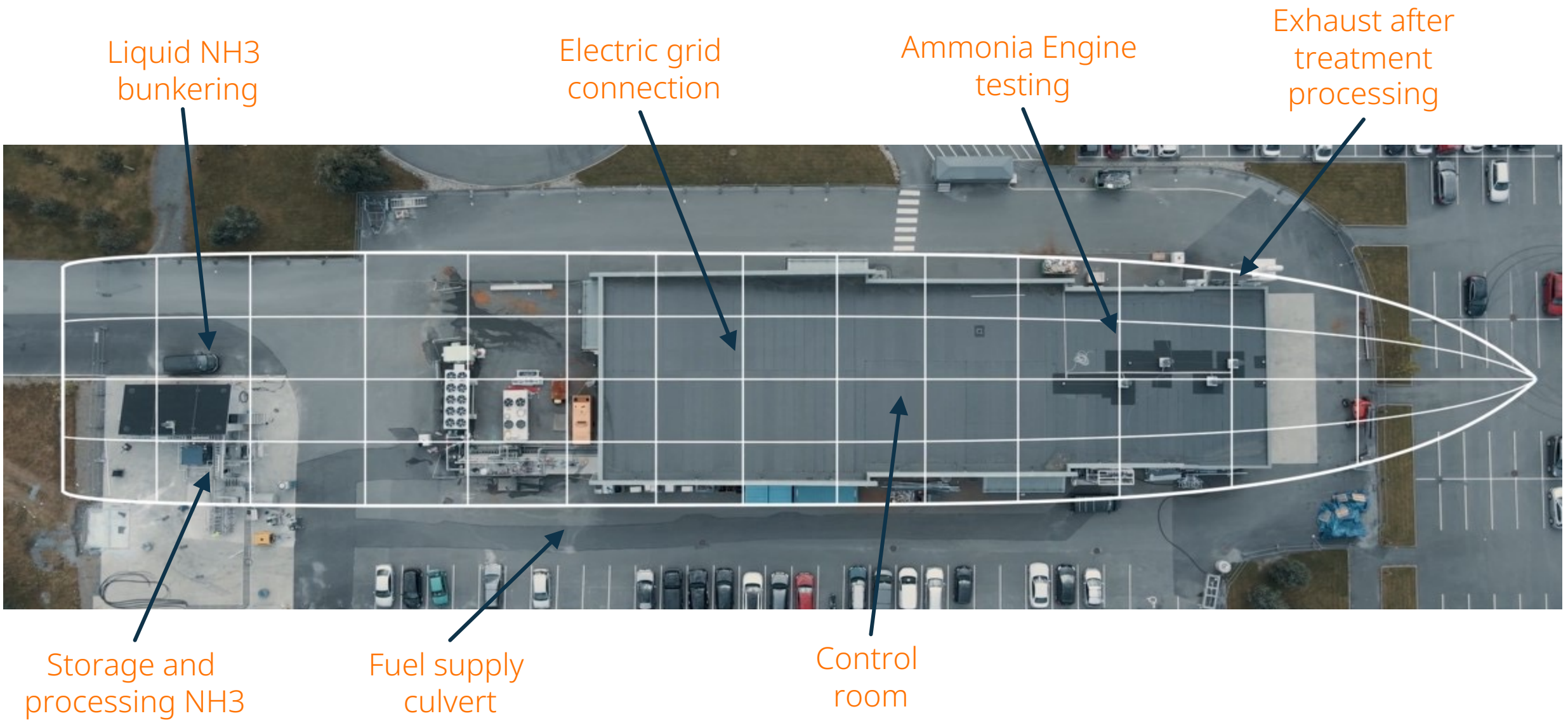
2020 - 2023



PARTNERS



The ship view of Demo 2000 ammonia engine testing





ACHIEVEMENTS

85+% Ammonia share

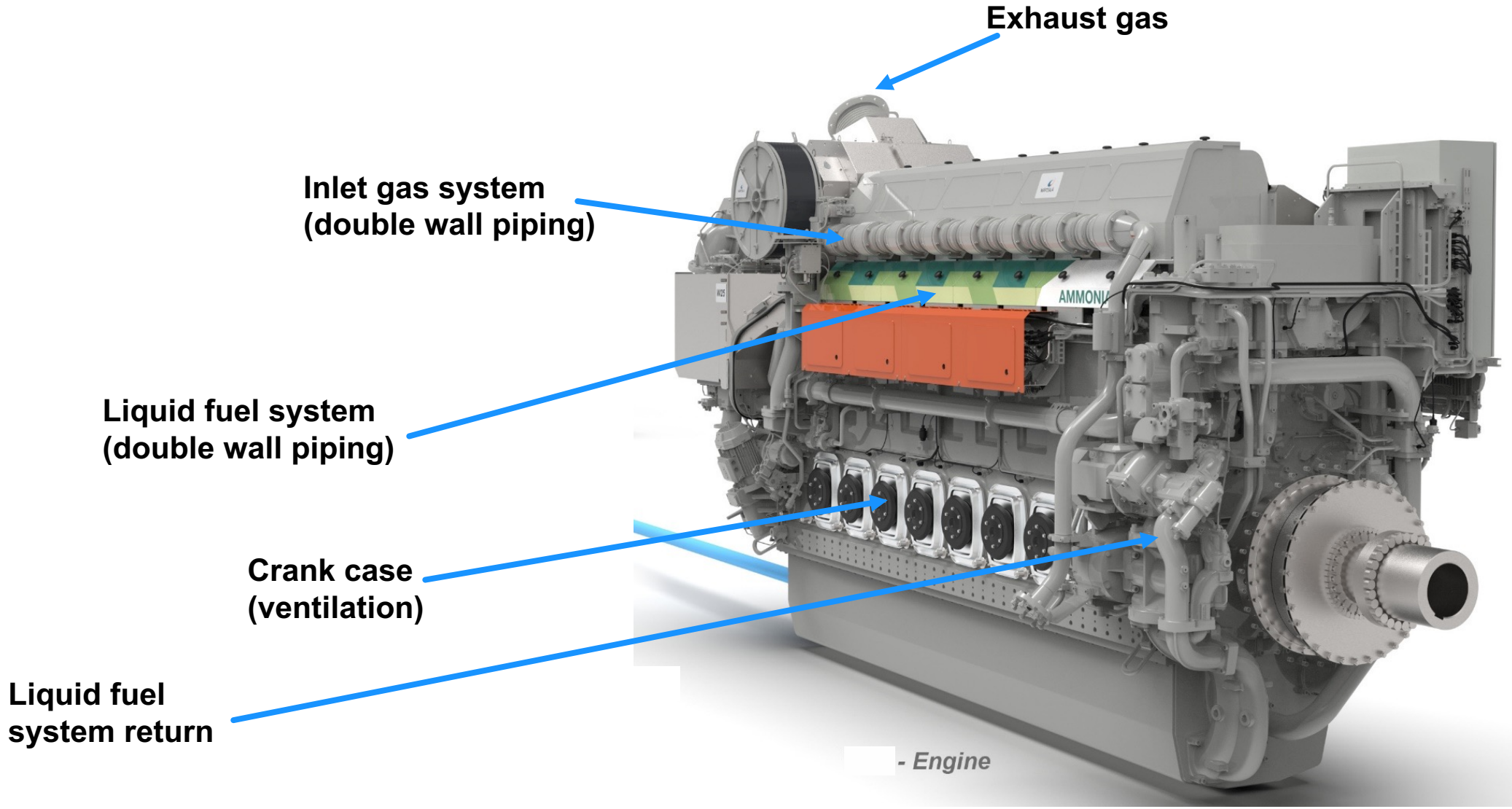
N_2O < 5ppm

NO_x = (**Tier III**)





Possible locations for Ammonia outlet/leakage



AMMONIA DETECTORS AND LEAKAGES

- Minor leakages have occurred during two years of testing.
- Quickly located and noticed by the ammonia detectors.
- Due to wrong material O-rings and faulty valves.

- In the beginning 100 ppm of ammonia readings were detected.
- After some investigations it was determined that the ammonia sensors were giving faulty readings.

LUBRICATING OIL

- After running the engine low pressure otto combustion mode with gaseous ammonia it was noticed that the lube oil had a ammonia odor.
- Samples were taken of the lube oil. Tests confirmed that the lube oil contained a small amount of ammonia.
- No changes were observed in the properties of the lubrication oil.

ENGINE OPERATION

- The engine operation has been smooth most of the times.
- Engine tests were done both with
 - I. low pressure ammonia in gaseous form
 - II. high-pressure ammonia in liquid form
- The challenge with the fuel handling control
 - pressure and temperature of ammonia
 - ammonia/diesel mix or ammonia/gas mix ratio
- The challenge is to keep the fuel on the correct phase at all times.
 - For a gas-fuelled engine to void condensation
 - Utilizing ammonia as liquid fuel to void evaporation

KEY LEARNINGS AMMONIA ENGINE TESTING

- Wärtsilä started first ammonia engine testing in research laboratory in Vaasa Finland summer 2021.
- Ammonia is widely used and well known chemical as fertilizer, refrigerating agent and in manufacturing processes.
 - Using ammonia as fuel in engines is in research phase.
- During normal operation ammonia engine room is gas safe space similarly to LNG engine room.
- Ammonia calibrated detectors are added in addition to gas detectors into the engine room.
- By utilizing high level of automation the need to enter ammonia gas containing space in case of ammonia leakage can be removed.



KEY LEARNINGS AMMONIA ENGINE TESTING

- Running the engine as premixed otto combustion mode will led to ammonia gas concentration to go up in the crankcase. Because of this engine operators can not go to the engine room straight after engine stop to open crankcase doors.
- When running ammonia engine with gaseous ammonia, ammonia odour can remain in the engine until the next day. It was measured proximately 10ppm of ammonia near the engine. Such small concentration of NH_3 are not dangerous.
- It was observed that ammonia can enter the lube oil through ammonia filled crankcase space. Changes in oil properties were not observed in more detailed laboratory tests. About 100 ppm of ammonia was measured to evaporate from the hot lubricating oil.
- When running the engine with liquid ammonia, the ammonia odour disappeared quickly.



WÄRTSILÄ

KEY LEARNINGS AMMONIA ENGINE TESTING

- To operate ammonia engine and perform maintenance personnel must have good level of ammonia training.
- When performing maintenance work on ammonia engine or systems suitable ammonia PPE should be used due to the toxicity of ammonia.
- During the testing of the ammonia engine no major ammonia leakages has occurred. Some small ammonia leakages have been observed.



CONCLUSIONS

- The ammonia engine tests have showed that with ammonia fuel handling system, safety equipment and updating of the engine, ammonia can be utilized as fuel with minor changes to the engine design.
- The toxicity of ammonia will require additional design elements for the fuel system, as well as for spaces with ammonia system components, so that an acceptable level of safety can be obtained.
- Ammonia production industry must provide sufficient level of green ammonia production in order enable the adaptation of green ammonia as marine fuel.
- Emission performance testing has shown that ammonia as fuel can provide excellent emission performance both in terms of GHG components and traditional pollutants.