

Risks for storage and bunkering Ammonia using the existing standards

Green Ammonia will be sued as fuel and energy storage How to gain the acceptance by the general public and authorities ? Our 3-Barrier Ammonia Storage Technology helps to convince

Today, Green Ammonia (NH_3) can be produced directly from water, nitrogen (from air) and with (renewable) electricity. It is known that ammonia can be stored as a liquid in large tanks or ship bunkers. Ammonia has a high energy density. It can be used as fuel (inter alia for ships) and fuel for power plants. Ammonia burns clean; does not produce CO_2 , only nitrogen and water.

Ammonia is produced, transported and stored on a global scale. Therefore, there are established standards for the safe handling, storage and transportation of ammonia.

Green ammonia has been favored as a fuel in several studies for maritime transport and as an energy carrier, as it offers the following advantages:

- ✓ It has an existing global logistics infrastructure
- ✓ It does not require extremely expensive cryogenic storage (as opposed to hydrogen)
- ✓ As a liquid, it has a high energy-density and provides sufficient energy storage for multi-week ship-cruises
- ✓ It can be used for internal combustion engines, for gas-turbines in power plants and in the future also for fuel cells
- ✓ It has a risk profile that can be managed using existing codes and standards.



The statement that ammonia risks can be managed using existing codes and standards is valid for industrial handling of ammonia (production, storage, transfer and transportation). **However we feel the safety standards now in force in industrial companies are not sufficient for the general public and authorities to accept ammonia as fuel and energy carrier.** Note that ammonia will be used in close proximity to the population.



To use green ammonia as fuel and energy storage, the general public and the authorities need a better understanding for the safe handling of ammonia (refer to the University of Cardiff Publication: Attitudes and Perception of Experts on Ammonia-Based Systems.

<https://www.cardiff.ac.uk/people/research-students/view/1185260-mercado-quati-rojo-andrea>).

In order to substantially increase the existing safety level first we have carried out an analysis of technical risks in the bunkering / storage of liquid ammonia. Find our conclusions below:

- Ammonia is not generally corrosive to the standard type of material, carbon steel. But, tanks can be affected by the internal and/or external environment.
- Normally small quantities of oil and water are contained in ammonia. Oil has no negative effect on service life. Water has a positive effect, this inhibits Stress Corrosion Cracking.
- Be aware liquid ammonia in the presence of oxygen can cause Stress Corrosion Cracking in carbon steels. The probability of Stress Corrosion Cracking increases with increasing yield strength of used materials and local hardness in the welds. Together with the applied stresses, it can be enough to initiate Stress Corrosion Cracking if oxygen is present in sufficient amounts.
- One has to rely on the ammonia supplier otherwise Stress Corrosion Cracking can be initiated. With the growing number of suppliers, however, an increased oxygen content cannot be ruled out.
- The key parameter for stress corrosion cracking is the oxygen content in the liquid ammonia. And air ingress in case of internal inspections is also a risk for Stress Corrosion Cracking.
- The sampling and analysis of ammonia-quality is very special.



We have developed the 3-Barrier Ammonia Storage Technology to completely eliminate the above mentioned risks:

- ✓ Quality deviations of the ammonia are no problem anymore. It cannot lead to any harm, like Stress Corrosion Cracking.
- ✓ It is resistant against any quality changes of ammonia.
- ✓ It provides a 100% safety level due to the additional safety barrier.
- ✓ It prevents every corrosion phenomena on the pressure-bearing wall, inside as well as outside.
- ✓ Because no Stress Corrosion Cracking is possible, one can use carbon steel with a higher allowed yield stress (higher strength).
- ✓ It contains a specially designed AMMO LASER Leak Detection System for detecting and monitoring ammonia leaks of the inner wall.
- ✓ It includes is a simple method of recurring testing of pressure shell using modern Non Destructive Testing while being on stream.
- ✓ It decreases thermal stresses on the pressure shell in case of the commissioning.
- ✓ It can be used for pressure-less bunkering of refrigerated liquid ammonia as well as for pressurized bunkering at approximately 20°C and 10 bar.
- ✓ In principle it is possible to retrofit existing tanks with our 3-Barrier Ammonia Storage Technology.
- ✓ Even an ammonia release through a failure of the safety valve can be excluded.
- ✓ It is based on known and well proven manufacturing technologies for vessels and tanks for the ammonia industry.
- ✓ Due to the many advantages mentioned above, the CAPEX and OPEX is ultimately lower than known bunker / storage facilities for ammonia.