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Thermal analysis of repurposing liquified natural gas tanks for liquid hydrogen storage

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Liquid Hydrogen (LH2) is emerging as a high potential energy storage medium in the accelerating Hydrogen economy to achieve net zero targets by 2050. LH2 possesses the advantage of high volumetric energy density compared to compressed gaseous Hydrogen. However, currently LH2 usage is restricted by both production and storage issues. Scalability and constructability limitations, capital cost for build new infrastructure, compatibility of materials for cryogenic temperatures, and cryogenic boil-off losses due to the low boiling point of LH2 limit the large-scale LH2 storage tank development. Pre-stressed concrete composite storage containers are frequently used to construct large-scale Liquified Natural Gas (LNG) storage facilities operating at cryogenic temperatures where structural rigidity is provided by the concrete. However, there is still a concern that, despite the relatively environmental stewardship of LNG, its long-term viability as a primary fuel tends to decline due to CO2 emissions. These infrastructures situated in energy export terminals with port infrastructures, and they'll be obsolete in the future with the elimination of hydrocarbons. If these hundreds of millions worth infrastructure can be repurposed to LH2 storage or any other purposes need for LH2 supply chain, it can drastically reduce the capital cost of new energy infrastructure required for commercial LH2 export and import. Therefore, this study examines the potential, challenges and required modifications to repurpose existing above-ground LNG storage tanks to store LH2, considering the thermal analysis.
In the current context, above-ground storage predominates among LNG storages due to their increased capacity, generally topping around 200,000 m3 ranging from 50,000 m3, in addition to less complicated maintenance and ease of installation. These tanks generally tend to be cylindrical, where the capacity differentiates on large scales based on demand. These tanks are developed over the years in 3 generations, increasing their safety, reliability, and capacity, known as single containment tanks, double containment tanks, and full containment tanks. In this study. a tank of size 200,000 m3 was modelled with a three-layer insulation system which falls under full containment configuration. Nickel steel and prestressed concrete were used as the materials of the inner and outer tank, respectively. The prestressed concrete tank section was simulated by incorporating reinforcements into concrete to model realistic scenarios of prestressed concrete.
The thermal analysis of this study consists of three different simulations to evaluate the 1. Temperature distribution across the tank shell with the existing insulation materials, 2. Applicability of vacuum insulation to minimize boil-off of LH2 with existing insulation materials, 3. Applicability of alternative insulation materials to minimize LH2 boil-off. As insulation materials, 1. multi-layer insulation, 2. fiberglass, 3. glass bubbles, 4. aerogel blanket, 5. perlite, and 6. aerogel powder were considered. LH2 boil-off quantity was calculated using both static and dynamic boiloff modelling techniques. The dynamic boil-off model utilizes the concept of the superheated vapour model which is based on the fact that liquid and vapour temperatures exist with a temperature gap in cryogenic storage tanks rather than at saturated equilibrium. This comprehensive analysis paves the way to identify technically and economically feasible solutions that can be incorporated into mega-scale LNG tanks during the conversion to LH2 tanks. Also, the results of this study can be utilized when developing new LNG tanks, so that the features required for LH2 storage can be incorporated in the designing process.

Submitters Country

Australia

Author: Dr BADUGE, Shanaka (The University of Melbourne)

Co-authors: Mr COSTA, Susiri (The University of Melbourne); Mr PREMAKUMARA, Amila (The University of Melbourne); Mr SAKVITHI, Hasala (The University of Melbourne); Dr THILAKARATHNA, Sadeep (The University of Melbourne)

Presenter: Mr COSTA, Susiri (The University of Melbourne)

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