OTC 19003

The Certification of FRP Pressure Vessels Intended for Marine CNG Transportation

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Abstract

The primary requirement for class approval of compressed natural gas (CNG) carriers is to certify the gas containment system. In the case of the Trans Ocean Gas method of CNG transport by ship, that means certifying the fibre reinforced plastic (FRP) pressure vessels intended to be used to store natural gas on a ship.

Det Norske Veritas (DNV) has issued rules for certifying FRP pressure vessels for marine CNG transport. The latest revision of these rules and guidelines is DNV-OS-C501, issued in January, 2005. Trans Ocean Gas will use these rules and guidelines to certify its FRP pressure vessels and systems for the marine transport of CNG.

In Line with the DNV mission, the DNV rules are focused on ensuring that a CNG carrier is as safe as, or safer than, an LNG tanker. The first question this raises is what is the level of safety of an LNG tanker? From statistical data, DNV has determined that the probability of a nonfatal incident is less than 10^{-4} (1 in 10,000) and that the probability of a fatality and or total loss of asset is less than 10^{-5} (1 in 100,000). These levels of probability include potential groundings and collisions. To ensure the corresponding levels of reliability are met, DNV has stipulated that the maximum probability of a failure shall be 10^{-5}. A leak is considered a failure.

The integrity of a FRP pressure vessel (probability of failure) can be estimated statistically through three tensile properties: static strength, static rupture (creep), and cyclic fatigue. To measure the performance of FRP pressure vessels within these three properties, one could physically test a significant number of full sized pressure vessels. The question is, how many are enough? As with any statistical analysis, the larger the sample the less the uncertainty. When the focus is to predict the probability of an occurrence to less than 10^{-5}, uncertainty must be as low as practically possible. However, to obtain a low level of uncertainty may take several years; which is directly tied to cost. A trade-off therefore exists between low uncertainty and time and cost of testing. Where time and cost are constraints, practicality is determined by the weight of these two criteria in completing the testing and analysis.

To reduce both time and cost, Trans Ocean Gas has elected to first characterize the materials selected by testing numerous coupons and then test a selected number of full sized prototype pressure vessels for correlation and analysis. The favourable outcome will be a close correlation and a low coefficient of variation (CoV). This will require the fewest number of full sized FRP pressure vessel to be tested to obtain the level of reliability and certainty required.

Material Characterization.

To characterize the tensile properties of the materials used to make a laminate shell of an FRP pressure vessel, numerous coupons will be tested. The coupons are made of unidirectional fibres set in the selected epoxy matrix. To obtain a reasonably low level of uncertainty, Trans Ocean Gas will test approximately 30 coupons for each property. The coupons will be prepared as per ASTM D3039. Coupon fabrication is scheduled for the first week in February 2007. Approximately one hundred coupons will be fabricated for testing.

Static Strength
Test approximately 30 coupons to estimate:

1. The mean static strength (stress) of the composite material at failure;
2. The standard deviation and coefficient of variation (CoV) about the mean;
3. Using strain gauges, the corresponding mean strain at failure;
4. Using strain gauges, Young's Modulus; and
5. The probability that the next coupon tested will fail when brought to a specified percentage of mean stress at burst.

By testing a number of prototype FRP pressure vessels to burst, the correlation factor between the mean strain at burst of the material characterized and the mean strain at burst of the outside of the laminate shell on the FRP pressure vessel can be calculated. Note: that the variation about the mean strain at burst of the pressure vessels is a measure of the material variation and fabrication process combined. To estimate the