## Experimental Studies of Boil-off Gas (BOG) Rates in Liquid Nitrogen and Liquid Methane

Fernando Perez<sup>s</sup>, Saif Al Ghafri and Eric May<sup>c</sup> Fluid Science and Resources Division, School of Mechanical and Chemical Engineering, University of Western Australia, Perth, WA, Australia eric.may@uwa.edu.au

To model boil-off gas (BOG) rates and rollover phenomena that can occur during the storage and transport of liquefied natural gas (LNG), a new apparatus has been constructed that permits measurements of vertical temperature gradients as well as boil-off gas flow rates and composition at both steady state and transient conditions, with operating temperatures as low as -200 °C and pressures between 0.2 and 10 bar. Cylindrical vessels with varying aspect ratios were used to store several litres of cryogenic liquid within a multi-stage thermostat that minimized heat leaks. The temperature distribution within the vessel was monitored using 35 calibrated platinum resistance thermometers, which also enabled the location of the vapor-liquid interface to be determined. Thermofoil heaters were mounted at different locations on the exterior of the vessel to deliver controlled amounts of heat flux into the sample, analogous to the types of heat leak cryogenic storage vessels undergo. The apparatus was commissioned using liquid nitrogen and liquid methane to quantify the ability to close the material and energy balances of the experimental system. When 4 W was applied continuously through the bottom of the vessel only, 97 % of the cumulative energy delivered was measured as either a latent or sensible heating of the liquid nitrogen; the 3 % error in the energy balance was attributed to the heat lost via conduction and radiation to the environment. The measured temperature distributions and evolution of the liquid-vapor interface were compared with the predictions of finite element and one-dimensional lumped element models. These measurements will ultimately be applied to multi-component LNGs to facilitate better, more cost-effective but safe designs of LNG transportation and storage vessels.