Announcing the Final Examination of Angela Krenn for the Degree of Master of Science in Physics

Date: Monday, November 2, 2015
Time: 9:00 a.m.
Room: PSB 160
Thesis title:
The safe removal of frozen air from the annulus of a liquid hydrogen storage tank

Abstract:

Large Liquid Hydrogen (LH_2) storage tanks are vital infrastructure for NASA. Eventually, air may leak into the evacuated and perlite filled annular region of these tanks. Although the vacuum level is monitored in this region, the extremely cold temperature causes all but the helium and neon constituents of air to freeze. A small, often unnoticeable pressure rise is the result. As the leak persists, the quantity of frozen air increases, as does the thermal conductivity of the insulation system. Consequently, a notable increase in commodity boiloff is often the first indicator of an air leak. Severe damage can then result from normal draining of the tank. The warming air will sublimate which will cause a pressure rise in the annulus. When the pressure increases above the triple point, the frozen air will begin to melt and migrate downward. Collection of liquid air on the carbon steel outer shell may chill it below its ductility range, resulting in fracture. In order to avoid a structural failure, as described above, a method for the safe removal of frozen air is needed.

Two potential methods for air removal are evaluated here. The first method discussed is the connection of a vacuum pump to the annulus which provides pumping in parallel with drainage of LH_2. The goal is to keep the annular pressure below the triple point so that the air continues to sublimate, thus eliminating the threat that liquefaction poses. The second method discussed is the application of heat to the bottom of the outer tank during tank drain. Though liquefaction in the annular space will occur, the goal of the heater design is to keep the outer shell above the embrittlement temperature, so that cracking will not occur.

In order to evaluate these methods, it is first necessary to characterize some the physical properties and changes that take place in the system. A thermal model of the storage tank was created in a numerical heat equation solver code (SINDA/FLUINT) to identify locations where air can freeze. This model shows the volume that is capable of freezing air under varying conditions. It is also necessary to characterize the changes in thermal conductivity of perlite which has nitrogen frozen into its interstitial spaces. The details and results of an experiment designed for that purpose is outlined. All data, including operational data from existing LH_2 tanks, is compiled and a physics-based evaluation of the two proposed air removal techniques is performed.

Due to small pumping capacities at low pressure and the large quantity of air inside the annulus, the pumping option is not deemed feasible. It would take many years to remove a significant amount of air by pumping while maintaining the annular pressure below the necessary triple point. Application of heating devices is a feasible option. For a specific case, it is shown that approximately 105 kilowatts of power would be required to vaporize the air in the annulus and keep the temperature of the outer tank wall above the freezing point of water. Several engineering solutions to accomplish this are also discussed.

Outline of Studies:
Major: Physics

Educational Career:
M. B. A. University of Central Florida, USA, 2006
B. S. Embry-Riddle Aeronautical University, USA, 2002

Committee in Charge:
Dr. Aniket Bhattacharya (Chair)
Dr. Subith Vasu Sumathi
Dr. Robert Youngquist (External Committee Member)

Approved for distribution by Dr. Aniket Bhattacharya, Committee Chair, on October 18, 2015.

The public is welcome to attend.