Contribution ID: **383** Type: **Contributed Oral**

C4Or1C-04: Liquid Hydrogen tank chill and no-vent fill prediction using computational fluid dynamics

Thursday 13 July 2023 10:45 (15 minutes)

Cryogenic tank chill and fill is an important cryogenic fluid management (CFM) technology that supports and enables many of NASA's long-duration space missions. For no-vent fill, the receiver tank pressure remains below the supply tank pressure during the entire duration of the fill so that the tank does not require venting. This is especially advantageous for tank fill operations in low gravity where the position of the liquid is not always known and venting the tank may cause loss of propellant by venting liquid. In lieu of expensive tests conducted on-orbit, accurate computational models capable of predicting receiver tank pressure during cryogenic propellant tank fill may be used to reduce system and propellant mass as well as mission risk. However, these numerical models must be validated or anchored to test data. This study presents a computational fluid dynamics (CFD) model with conjugate heat transfer that is used to predict a liquid hydrogen tank chill and no-vent fill ground test conducted at Lewis Research Center (now Glenn Research Center) in 1991. The specific test case chosen for model validation implemented an upward-facing jet near the bottom of a cylindrical 34 liter tank. CFD predictions are compared to experimental measurements of tank pressure, fill level, fluid temperatures, and wall temperatures. The CFD results show reasonable agreement to the test data but overpredict the pressure collapse near the end of the fill despite the liquid jet penetrating the liquid-vapor interface. Several sensitivity studies are considered due to notable uncertainties in the experiment.

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Session Classification: C4Or1C: Hydrogen V: Aerospace Tanks