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C3Po1E-01: Progress on the investigation of the delay in boiling of liquid nitrogen in a capillary channel

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A clear boiling delay was observed during imbibition of room temperature liquids into capillary channels, in which nucleate boiling is postponed to a temperature above the saturation temperature of the liquid. This boiling delay is also expected to influence the wicking behavior because similar effect are involved, for example the effect of surface tension, viscosity and evaporation. Wicking into microstructures of porous materials often happens at elevated wick temperatures, especially in cryogenic applications. The knowledge of boiling delay can be applied in for example cryogenic propellant management devices used in space applications or dry-shippers a container lined with porous material that absorbs liquid nitrogen.

Several imbibition regimes were observed depending on the channel temperature. Typically, the imbibition velocity increases with channel temperature due to the reduction of viscosity until the saturation temperature of the liquid is reached. Once the temperature exceeds the saturation temperature of the liquid, the evaporation rate at the surface of the meniscus accelerates rapidly, however nucleation inside the liquid phase does not occur initially. The effect of evaporation gives rise to a reducing imbibition velocity, which can be explained by two effects. The increase in momentum of the vapor during evaporation gives rise to a backpressure and the increased vapor velocity increases the viscous contribution of the vapor, which is often neglected in the low temperature regime. At higher elevated temperature the nucleation of vapor bubbles is no longer delayed and vapor is no longer only generated at the liquid front, which is followed by a regime where the liquid no longer enters the channel similar to the Leidenfrost effect. At cryogenic temperatures the specific heat capacity and latent heat of evaporation can be an order of magnitude lower than their room temperature counterparts, therefore a setup is designed to study the boiling delay at cryogenic temperatures.

The experimental setup must adhere to several requirements regarding temperature control, background gas control, and optical access. A method to reduce the temperature of the capillary channel to below the saturation temperature of liquid nitrogen is developed. At this temperature nitrogen and oxygen begin to condense on parts of the setup, therefore the background gas has to be controlled taking into account the evaporation of nitrogen from the channel. An optical setup is being implemented to have visual access to the test section without compromising the thermal insulation properties of the setup. The challenges for this experimental setup are discussed together with their solutions.

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