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Flow of nitrogen gas in a liquid helium cooled vacuum tube: Condensation heat transfer

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Linear accelerators (LINACs) using superconducting radio frequency (SRF) technology comprise of a long string of SRF cavities housed in discreet cryomodules. This cavity string is operated immersed in liquid helium (LHe) with high vacuum on its inside. Sudden loss of this cold vacuum to surrounding atmosphere perceivably is the worst failure mode of the LINAC. An accidental rupture at any cryomodule interconnect will initiate an air in-flow, which will solidify on the inner wall of the cold cavity and transfer heat to the LHe bath. Here, we study such a condensing flow with an emphasis on the associated heat deposition onto the cold walls, and the subsequent heat transfer to LHe. The flow is generated by rapidly venting a large reservoir of nitrogen gas to a long vacuum tube immersed in 4.2 K LHe. Experiments are carried out with different mass in-flow rates of nitrogen, and the rise of the pressure and temperature of the tube are recorded at several locations along the flow. As the gas pressure in the tube rises we observe that the rate of heat deposition due to condensation initially increases, attains a maximum, and then sharply drops. Irrespective of the mass in-flow rate of the gas (severity of the loss of vacuum accident) the maximum rate of condensation heat transfer to the tube occurs when the tube temperature is in 22-26 K range, and the pressure in the tube typically below 1 kPa. These observations are discussed in context of the cryopumping theory. With increasing gas pressure the tube temperature continues to gradually rise and eventually attains a steady value. The estimate of the peak heat load to the LHe bath is deduced from the maximum temperature attained by the tube.

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