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The Percolative Scale-Free Nature of the Boiling Crisis

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Abstract

We will present the results of theoretical and experimental investigations suggesting that the boiling crisis is the outcome of an instability in the bubble interaction process.

This instability is described by a percolation model using three inputs: nucleation site density, footprint radius of individual bubbles, and product of growth time and bubble departure frequency. At critical combinations of these parameters, the probability distribution of the bubble footprint areas becomes scale-free (i.e., it is a power-law with a negative exponent smaller than 3). This observation is the signature of the boiling crisis. Beyond this critical point, discrete bubbles merge abruptly into one large vapor cluster covering the entire boiling surface.

We demonstrate this hypothesis with experimental results obtained using high-resolution optical techniques (e.g., infrared thermometry and vapor phase detection) on plain and engineered surfaces in both pool and flow boiling conditions.