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A comparative study of rapid chill-down technologies in cryogenic applications

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Transporting cryogens, particularly for cryogenic propellant fueling, through pipelines from a storage tank is an indispensable process for undertaking a stable cryogenic mission. When cryogenic liquids are introduced into flow components at ambient temperature, they are bound to encounter vigorous two-phase instabilities including boiling and evaporation. The preliminary step of lowering the temperature of hardware to the cryogenic fluid's saturation level, a process referred to as "chill-down" or "quenching," is fundamental for ensuring the delivery of a cryogenic liquid devoid of vapor. Achieving temperature reduction via phase change in heat transfer comes at the cost of using up irreplaceable propellant. Consequently, it is of paramount importance to shorten the chill-down period and lessen the mass load of the cryogenic fluids being employed. To reach this purpose, the present study is aimed to evaluate the effectiveness of rapid chill-down strategies by examining an insert of passive device against a surface treatment approach in the flow passage. Through analysis across various Reynolds numbers, it becomes clear that each method offers unique benefits regarding liquid mass consumption and the time required for chill-down process. An in-depth examination of the experimental data sheds light on how these approaches affect the thermal and hydraulic dynamics throughout the cooling phase.

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