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Experimental Study of the Cooling Properties in Low-Pressure Flash Evaporation

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Extended Abstract

Flash evaporation is the rapid evaporation of liquid induced by immediate superheating when the surrounding pressure around the liquid suddenly descends below the saturation pressure corresponding to the liquid temperature[1]. The flash evaporation process involves intense heat transfer and phase change, resulting in high heat flow density, quick evaporation speed, and full utilization of the work material's latent heat. This technique has been widely used in several sectors, including spacecraft cooling[2], pharmaceutical drying[3], electronic components[4], and saltwater desalination[5]. Because of the low natural pressures in the areas where it is utilized, flash vaporization technology has attracted a lot of interest, especially in aircraft applications. Agencies such as NASA have identified compact flash evaporator system as one of the alternative methods of heat dissipation for the crew exploration vehicle thermal control system[6-8].

The flash evaporation process is primarily based on the flash morphology, which is divided into spray flash evaporation and pool flash evaporation, with pool flash evaporation being classified as static pool flash evaporation or circulating flash evaporation based on whether the liquid has a horizontal flow rate. Currently, the majority of research focuses on the mechanism of static pool flash evaporation in a closed cavity, as well as the cooling effect of spray flash evaporation. However, for flash evaporation cooling in space thermal control, the system is vacuumed. Given the vehicle's carrying capacity, the objectives are minimal working fluid flow and maximum flash efficiency, for which present research on flash cooling is insufficient.

In this study, a low-pressure flash evaporation system with a low working flow rate was developed to accommodate the temperature control requirements of the aircraft's electronics compartment. The core test segment is a rectangular structure with the upper layer acting as the heated surface and the lower layer serving as the cooling surface. Energy exchange between two heat transfer surfaces in the form of thermal radiation. Water was used as the cooling medium, with a peristaltic pump accurately controlling the flow rate. The flow rates varied from 0.04 g/s to 0.093 g/s, which is lower than the majority of the flash evaporations that have been studied; The experimental pressure varied from 5Kpa to 15Kpa, which was adjusted by the valve of the vacuum pump. The results demonstrate that the cooling properties of flash evaporation are greatly influenced by its initial superheat. Higher initial superheat can lead the cooling water to surpass the critical heat flow density, significantly reducing the effectiveness of flash evaporation. On the other hand, more cooling water flow is not always preferable. At absolute pressures of 10 Kpa, the cooling power of the cooling water flow rate of 0.08 g/s can reach 180 W, and increasing this flow rate reduces the efficiency of flash evaporation. The cooling effect of flash evaporation is less affected by vacuum pressure than the previous two. Vacuum pressures ranging from 5kPa to 15kPa have less than 10% influence on flash evaporation efficiency and surface temperature cooling.

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