Experimental Thermal and Fluid Science 35 (2011) 788–796

Contents lists available at ScienceDirect

Experimental Thermal and Fluid Science

journal homepage: www.elsevier.com/locate/etfs

Influence of gravity on pool boiling on a flat plate: Results of parabolic flights and ground experiments

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ARTICLE INFO

Article history:
Received 28 January 2010
Received in revised form 31 March 2010
Accepted 29 April 2010
Available online 12 May 2010

Keywords:
Nucleate boiling
Microgravity
Boiling regime
Boiling heat transfer mechanism

ABSTRACT

Experiments of pool boiling of HFE7000 on a flat plate have been performed in both earth and microgravity conditions in parabolic flights. The effects of pressure, subcooling and gravity are studied. Experiments show that in fully developed boiling regime gravity and subcooling have a weak influence on heat transfer. By identifying mechanisms that control heat transfer, the weak influences of gravity and subcooling are explained.

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1. Introduction

The study of boiling in microgravity is of a great interest either for the understanding of the physical mechanisms but also for industrial applications. The present study concerns the heat and mass transfers in the cryogenic tanks of the launchers. A French-German research programme called COMPERE (French acronym for the behaviour of propellants in reservoirs) is dedicated to the upper stage of the European launcher Ariane V. The cryogenic Liquid Oxygen (LOX) or Hydrogen (LH2) are pressurised by their vapour or a non-condensable gas. During the different phases of the mission (propelled phase, ballistic phase) it is important to control the phase distribution and the evolution of temperature and pressure inside the reservoirs. The evolution of these parameters strongly depends on heat and mass transfers. During the ballistic phase of the mission, the tank wall is heated by solar radiation and thermal dissipation due to engine and electrical devices. Since there is no thermal convection in microgravity, the heat transfer between the heated wall and the liquid is mainly due to heat conduction and the wall temperature can become greater than the required temperature for the onset of nucleate boiling. The study of boiling in microgravity is thus of particular interest in this situation. An experimental programme has been developed to study pool boiling on a flat plate in normal gravity and in microgravity conditions in parabolic flights in aircraft. For safety reasons experiments are not performed with cryogenic liquids but with a refrigerant HFE7000.

The study of pool boiling in microgravity has begun in the 60's with the NASA Space programme with experiments performed during short test time by Merte and Clark [1] or Siegel [2]. Contradictory results on the effect of gravity from these earlier experiments have been reported. During the 80's and 90's, experiments on flat heated plates, have been carried out during longer microgravity periods in parabolic flights or sounding rockets by Zell et al. [3], Lee et al. [4], Ohta [5] and Oka et al. [6]. These experiments have shown the existence of stable boiling regimes in microgravity over long periods. In a review of these experiments Straub [7] remarked that gravity has a relatively weak influence on heat transfer in nucleate boiling but it strongly affects the dry out of the heated plate, reducing significantly the critical heat flux in microgravity. Nevertheless the influence of gravity is still not clear; for example experiments performed by Zell et al. [3] and Lee et al. [4] both with R113 on a flat plate gold coated heater do not display the same results: Lee points out an improvement of heat transfer in microgravity whereas Zell observes the opposite trend.

The influence of pressure has been studied by Straub [7], who clearly shows that in earth gravity conditions, an increase of pressure causes an increase of heat transfer. The effect of liquid subcooling on heat transfer has been studied by several authors like Lee et al. [4], Ohta [5] or Oka et al. [6]. Unfortunately in these experiments subcooling was changed by varying the pressure. It is

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doi:10.1016/j.expthermflusci.2010.04.010