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Zone of Influence of Porous Suction Tubes in Condensing Heat Exchanger for Space Systems

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ABSTRACT

A "next generation" condensing heat exchanger for space systems has to satisfy demanding operational requirements under variable thermal and moisture loads and reduced gravity conditions. Mathematical models described here are used to investigate transient behavior of wetting and de-wetting dynamics in the binary porous system of porous tubes and porous cold plate. The model is based on the Richard's equation simplified for the zero-gravity conditions. The half-saturation distance or the zone of influence of the porous annular suction tubes on the cold-plate porous material will be in the range of 1 to 10 cm for the time scales ranging from 100 to 10,000 seconds and moisture diffusivity in the range of $D = 10^{-4}$ to 10^{-6} m^2/s. Spin-echo MRI experiments on horizontal thin-section porous Aquafoam^{TM} samples demonstrated powerful ability of magnetic resonance to measure moisture transport, wetting fronts, and saturation distribution in simulated near zero-gravity conditions for opaque porous media.

INTRODUCTION

NASA deep-space manned missions and LEO missions (e.g., ISS, STS) require a system to maintain the cabin air environment at livable and comfortable conditions for human habitat. In particular, long-duration manned deep-space missions depend on the reliable, high power-to-weight ratio, and hopefully passive CHESS. Several different heat exchanger designs, including systems based on PM, have been used in the past (Petter et al., 1990; Unger et al., 1992; Scull et al., 1998; Westheimer and Daidzic, 2003; Althausen et al., 2006; Daidzic et al., 2007a). All of these systems had the main task of removing heat and moisture from the re-circulating cabin air. Porous media has a long history of applications in space systems due to its desirable inherent properties of containing liquid in reduced gravity environment. In addition, unsaturated PM provides capillary driving force which in the absence of adverse gravitational potential may be sufficient for reliable transport of the liquid (wetting) phase.

A particularly troublesome problem in long-term variable-g operation of CHESS is the occurrence of biofouling and clogging (Roman et al., 1999; Stevik et al., 2004; Daidzic et al., 2005a). This problem requires a special attention. Some recent results on hydraulic properties of clogged PM for CHESS were reported in Daidzic et al. (2005a).

A "next generation" CHESS has to satisfy strict operational demands including the relatively frequent shut-downs and restarts and enduring almost continuously varying thermal and moisture loads. A new system first proposed by the present author in (Westheimer and Daidzic, 2003; Daidzic et al., 2005a; Daidzic et al., 2007a) is based on a finned annular PT's and the CPP that can be manufactured of material with good thermal and wetting properties.

One of the main candidates for the CPP was graphite. However, graphite which has excellent heat conduction properties exhibits poor wetting characteristic. PT's act as an interface between the bulk coolant liquid phase and the CPP (Daidzic et al., 2007b). The CPP has the main task to "communicate" with the moist cabin air and remove heat and moisture from it which is then transported to the coolant water in PT's. The CPP may or may not be fully saturated while PT's, with much smaller pores, normally always are.

Regarding the dynamic response of the system we are particularly concerned with the transients of moisture transport under saturation (wetting, imbibition) and de-saturation (de-wetting, drainage) conditions. In order to