Flow in parallel pipes with evaporation is a common occurrence in heat exchangers. Recently it is also associated with solar power plants based on trough technology where solar radiation is focused on a pipe heating the fluid within the pipe. At the present synthetic oil is used as the heated fluid and steam is generated in a secondary heat exchanger. Since the purpose is to generate steam it would be more efficient to evaporate water directly within the heated pipes, referred as Direct Steam Generation (DSG). In this case, however maldistribution of the flow rate within the parallel pipes may occur.

The evaporation of a flowing fluid in a pipe exhibits an “abnormal” behavior. Namely, the pressure drop in a pipe as a function of the flow rate has an “abnormal” range where the pressure drop decreases with increasing of the flow rate, unlike the flow of single phase where the pressure drop is a monotonic increasing function of the flow rate. This behavior may result in multiple steady state solutions for flow in parallel pipes with common inlet and outlet manifolds. The so called “Ledinegg instability” causes some of the steady state solutions to be unstable and as a result the flow may be distributed unevenly among the parallel pipes even for equal heating of all pipes. This is quite an unfavorable phenomenon.

A model for the calculation of the multiple steady states and their stability is presented. (Natan et al., 2003, Minzer et al., 2006). The transient behavior of this complex system can be calculated using a simplified model (Minzer et al, 2006) or a more accurate model based on the local flow patterns that are developed along the pipes due to evaporation (Taitel and Barnea, 2011). The theoretical results are confirmed experimentally.

Two control methods for the elimination of the uneven flow distribution that results from Ledinegg instability are proposed. The 1st method is based on controlling the exit quality of each pipe (Taitel et al., 2008). The 2nd method is based on the observation that multiple steady states are absent if the liquid enters the heated pipes as saturated liquid.

References:


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