

STUDY OF CONDENSATION IN
A HEAT PIPE

BY

CHITRA RAJAGOPAL
DEPARTMENT OF CHEMICAL ENGINEERING

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CERTIFICATE

This is to certify that the thesis entitled "Theoretical Analysis of Condensation in Heat Pipes" submitted by Chitra Rajagopal in fulfilment of the requirements for the degree of 'Doctor of Philosophy' to the Indian Institute of Technology, Delhi, is a record of the candidate's own bonafide research work, carried out under our guidance. The matter embodied in this thesis has not been submitted in part or in full, elsewhere, for the award of any degree or diploma.

Dr. P.D. Grover
Professor & Head
Centre of Energy Studies
I.I.T. Delhi - 110016

Dr. S. Subrahmaniyam,
Lecturer,
Chemical Engineering Department
I.I.T. Delhi - 110016

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ABSTRACT

A review of the literature on heat pipes indicates that extensive work on the evaporator section and on the various operating limits of the heat pipe are available. The condenser section which offers a significantly large resistance to the overall heat transfer (21) needs more attention and further study especially with regard to the local variation of condensation heat flux which is related to the two-phase flow dynamics.

The present work is a theoretical study of condensation in heat pipes. Mass, momentum and energy balance equations for the condensate film, are written in a differential form. The equations are solved by the integral method. Condensation in heat pipes with vertical and horizontal orientation is presented. The cases studied include wickless and wick-ed heat pipes, subjected to both constant wall temperature and uniform heat flux. The variation of condensate film thickness as influenced by the local flow rates of vapour and liquid and local heat transfer coefficient /Nusselt number with axial and circumferential position are presented and discussed.

The effect of the interfacial shear stress, arising both due to the relative motion of vapour and liquid and due to the condensation of vapour normal to the interface, on the condenser characteristics of both wickless and wick-ed

pipes has been considered.

The effect of the parameters such as the temperature difference across the condensate film, tube diameter, operating pressure, working fluid properties and the wick variables such as the mesh number, number of layers and the material of construction of the wick, on the condenser characteristics is discussed.

The local and average heat transfer coefficients and the condenser length required for condensing a given quantity of vapour, are compared for the various cases considered. For example, the average heat transfer coefficient, for a wickless water heat pipe of tube diameter 0.0221 m operating at 100°C, with ΔT of 20°C and an inlet vapour Reynolds number of 10, is about 10% higher than a similar pipe with a ΔT of 0.5°C while the required condenser length is 36 times lower. The increase in inlet vapour Reynolds number from 10 to 80, decreases the average HTC by nearly 3% and increases the required condenser length 12 times. The increase in operating temperature from 100°C to 140°C increases the average HTC by 53% and decreases the required condenser length nearly 2.1 times.

A sodium heat pipe condenser, operating at 870°C is found to have an average HTC 97 times higher than that

for a water heat pipe while an ammonia heat pipe, operating at 21°C has an average HTC 1.53 times lower than that for water. The length of the condenser for sodium is 130 times lower than the length of the water condenser while the length of the ammonia condenser is 1.8 times more than the length of the water condenser.

In a vertical wick-ed heat pipe condenser as the mesh number increases from 50 to 200, the average HTC is found to increase nearly 2.2 times and the condenser length is found to decrease 1.9 times. As the number of wick layers increases from 2 to 16, the average HTC decreases by nearly 77% and the condenser length increases by 30%. When the material of the wick is changed from copper to SS, the average HTC is seen to decrease by 45% and the condenser length is found to increase 2.11 times.

The average HTC for a vertical wickless water condenser is 2.88 times higher and the condenser length is 2.6 times lower than that for a corresponding horizontal wickless condenser, other operating conditions and tube geometry being the same. A vertical wick-ed pipe condenser lined with 8 layers of 200 mesh wick is found to have an average HTC 3.6 times higher than that of a corresponding wickless condenser while the condenser length is 5.4 times lower.

Comparison of the condensing coefficients obtained in the present study with experimental data and semi-empirical results of earlier workers in the field showed a fair degree of agreement for the vertical and horizontal wickless condensers. Due to the paucity of work on the condensation in wick-ed pipes, only limited comparisons are made.

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