FLOW BOILING OF MIXTURES OF REFRIGERANTS

R-12 AND R-13 IN A HORIZONTAL TUBE

by

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DEDICATED TO MY GRANDMOTHER

CERTIFICATE

This is to certify that the thesis entitled 'Flow Boiling of Mixtures of Refrigerants R-12 and R-13 in a Horizontal tube' being submitted by Mr. Vinod Kumar Jain to Indian Institute of Teohnology, Delhi, for the award of the Degree of Doctor of Philosophy in Mechanical Engineering, is a record of bonafide research work carried out by him. He has worked under my guidance and supervision and has fulfilled the requirements for the submission of this thesis, which in my opinion has reached the requisite standard.

The results contained in this thesis have not been submitted in part or in full, to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

The replacement of conventional fluorocarbon refrigerants in vapor compression machines by their suitable mixtures (such as R12, R13 mixture) has been shown to be advantageous by a number of researchers, especially in situations involving substantial change in the temperatures of the coolants in the condenser and the evaporator. However, this suggestion has not as yet been practically implemented by industry mainly because of lack of reliable information on heat transfer performance of these mixtures during evaporation and condensation. In the present work, an attempt has been made to provide reliable experimental data and design equations for prediction of heat transfer and pressure gradient in flow boiling of R12, R13 mixtures.

A well instrumented 10 KW boiling loop has been rigged up to carry out the experimental studies. The details of this set up are described. The test section as also the complete set up has been 'calibrated' by taking proofing runs with water and pure R12. The data on local values of heat transfer coefficient and pressure drop for boiling of mixtures of R12 and R13 (containing 10,20 and 30 per cent by weight of R13) flowing inside a horizontal copper tube of 12.6 mm ID at an average saturation temperature of 7.2°C

(suited to space conditioning applications) have been taken over a wide range of values of other parameters viz. heat flux 25000-0 W/m^2, vapor quality 0.15-0.9 and mass velocity 90-250 kg/s-m^2. To enable direct comparison of the performance of mixtures vis-a-vis pure R12, similar data on flow boiling of R12 have also been taken.

Thorough qualitative as well as quantitative analyses of the data have been carried out. The data are classified as lying in the FCV zone, NB zone and transition zone on the basis of heat flux vs. temperature difference plots on linear scale while identification of flow pattern has been done on the basis of visual observations. The dependence of heat transfer coefficient and pressure gradient on mass velocity, vapor quality and heat flux have been found to be similar to those observed with pure refrigerants. However, a delay in the occurence of dryout region is observed with mixtures.

The experimental results indicate appreciable drop in the values of heat transfer coefficient (upto 50 per cent) and pressure gradient (upto 40 per cent) for flow boiling of refrigerant mixtures in comparison with the corresponding values for pure R12. The drop in heat transfer coefficient is found to be more predominant in the NB zone than in the FCV zone. The qualitative analysis reveals that this reduction in heat transfer could mainly be attributed to the multifactorial influence of mass transfer resistance on flow boiling phenomenon. In contrast, the reduction in pressure gradient seems to be mainly related to the changes in the thermophysical properties of the liquid and vapor phases arising from mixing of R13 in R12.

The quantitative analysis of the data has also been carried out to identify/develop suitable correlations for prediction of heat transfer coefficient and pressure gradient in flow boiling of these refrigerant mixtures. The thermophysical properties of mixtures needed for this analysis have been obtained by using standard prediction techniques. The details of these techniques as also typical values of the various thermophysical properties are presented. Statistical evaluation of the existing correlations for prediction of heat transfer coefficient in mixtures revealed systematic deviations, and therefore, new correlations have been developed. The genesis of the development of these correlations is presented in detail. The new correlations have been obtained by combining Dembi's pure fluid correlations for FCV and NB zones (identified to be the best available on the basis of a detailed statistical analysis) with 'suitably optimized' correction factor of Calus and Rice to incorporate the effect of mass transfer resistance. These correlations are able to predict the experimental data with mean absolute fractional deviation and root mean square error of 0.121 and 0.147 in FCV zone and 0.104 and 0.130 in the NB zone. The two correlations have also been appropriately 'unified' to enable prediction of heat transfer coefficient in the entire boiling range. Alternative approaches at development of unified correlations for prediction of heat transfer coefficient in pure fluids, and in mixtures, have also been explored and their results discussed.

A statistical evaluation of various existing correlations for prediction of pressure drop in flow boiling of refrigerants has also been done against a broad based data file. The general deficiencies existing in these correlations have been brought out and discussed in detail. The best correlations amongst them are able to predict satisfactorily the data on mixtures, provided prevailing local thermophysical properties of R12-R13 mixtures are used during computations.

The implications of the experimental results from the point of view of application of refrigerant mixtures in vapor compression machines have also been indicated. The changes in the design which could partially offset the effect of observed reduction in heat transfer coefficient with refrigerant mixtures are discussed.

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