TWO PHASE FLOW THROUGH CAPILLARY TUBES

BY

ALY ABDEL AZIZ EL AZIZY

B.SC. (MECH. ENG.), AIN SHAMS UNIVERSITY

A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

M.Sc.

DEPARTMENT OF MECHANICAL ENGINEERING

FACULTY OF ENGINEERING

AIN SHAMS UNIVERSITY

1981

TWO-PHASE FLOW THROUGH CAPILLARY TUBES

BY

ALY ABDEL AZIZ EL AZIZY

(B.Sc., AIN SHAMS UNIVERSITY,MECH.ENG.)

A THESIS

SUBMITTED IN PARTIAL FULFILLMENT

OF THE REQUIREMENTS FOR THE DEGREE

OF M.Sc. IN MECH. ENG.

SUPERVISED BY

Prof. Dr. Abd-El Monem A. Rizk
Professor of Mech. Eng.,
Ain Shams University

Prof. Dr. Hussein Z. Barakat
Professor of Mech. Eng.,
Ain Shams University

Examiners	Signature
Prof. Dr. Alaa El-Din Al-Hefny Mech. Eng. Dept., Alexandria University	..M..A.El-H...
Prof. Dr. M. Sobhy Abd-El-Salam Mech. Eng. Dept., Cairo University	..M.S.Abdel-Salam
Prof. Dr. Abd-El-Monem A. Rizk Mech. Eng. Dept., Ain Shams University	...A.M.Rizk.....
Prof. Dr. Hussein Z. Barakat Mech. Eng. Dept., Ain Shams University	....

بسم الله الرحمن الرحيم

PREFACE

This dissertation is submitted to Ain Shams University for the degree of Master of Science in Mechanical Engineering.

The work included in this thesis was carried out by the author in the Department of Mechanical Engineering, Ain Shams University, from 1977 to 1981.

No part of this thesis has been submitted for a degree at any other university.

a

ACKNOWLEDGEMENT

The author expresses his appreciation for the cooperation and assistance of the supervisors Prof. Dr. A.M. Rizk and Prof. Dr. H.Z. Barakat, Energy & Automotive Eng. Dept. Faculty of Engineering, Ain Shams University, and for the technichans of "Refrigeration and air conditioning laboratory" for their helpful cooperation. The author wishes to present his gratitude for the constructive suggestions and the fruitful discussions received from the supervisors during the course of the research work presented in this thesis.

Last but not least the author wishes to express his sincere appreciation to his mother and his wife whose patience and constant encouragement constituted a major source of inspiration for him during the whole period of study.

TABLE OF CONTENTS

LIST OF FIGURES

Page

Page

TWO PHASE FLOW THROUGH CAPILLARY TUBES

"SUMMARY"

In the present work the pressure gradients due to friction during the adiabatic flow of flashing two phase mixtures in capillary tubes were investigated at different values of Reynold's number. For this purpose, a refrigerating machine was suitably prepared and instrumented to allow simultaneous flow of vapour and liquid through the capillary tube and to measure the pressure and temperature distributions along the tube length, refrigerant flow rate and the supplied electrical heat energy. Tests were carried out on horizontally, straight capillary stainless steel tubes using three bores1.3, 1, 0.8 millimeter. The capillary tube was insulated to obtain an adiabatic flow of R-12 refrigerant.

A method based on experimental data was developed to obtain the two-phase friction factor. In this method average physical properties were used in calculating the different parameters encountered. Another alternative procedure was provided for calculating frictional pressure drop, that is to avoid use of the friction factor equation and to use correlations for the two-phase multipliers instead.

The results of the present work indicated that :

1- The friction factor correlations for flow inside smooth tubes are applicable to single phase flow in small bore tubes such as used to date, as refrigerant restrictors.

2- For the same tube bore, the friction factor in two-phase flow decreases with the increase of Reynold's number and the maximum value for both Reynold's number and the friction factor took place at the larger capillary tube bore.

3- For the same Reynold's number and the same tube bore, the friction factor in single phase flow is higher than that obtained in two-phase flow.

4- For the same tube length and inlet conditions (pressure, temperature and degree of liquid subcooling), the mass rate of flow will increase with the increase of the tube bore.

5- The experimental results obtained in this work for the relationship between the Lockhart & Martinelli parameter and the two-phase friction multiplier are in good agreement with those obtained using the critical pressure equation suggested by Martinelli and Nelson (16). On the other hand some of present work results have had a higher values of this multiplier than those in critical pressure case.

NOMENCLATURE

A	Cross sectional area, m^2
A_s	Surface area, m^2
C_p	Specific heat at constant pressure, J/kg^o
D	Capillary bore diameter, m
F	Force, N
f	Single phase coefficient of friction.
f_m	The coefficient of friction for the two-phase mixture.
G	Mass flux or mass flow rate per unit area, $kg/hr\ m^2$
g	Gravitational acceleration, m/sec^2.
h	Specific enthalpy, KJ /kg.
I	Flow meter current, Amp.
j	Volumetric flow per unit area, m/hr.
L	Total tube length, m.
l	Distance along the tube length, m.
$\dot{m}$	Mass flow rate, kg/hr.
n	Exponent in Blasius equation.
P	Absolute pressure, N/m^2
R	Electric resistance, ohm.
S	Specific entropy, kJ $/kg^oK$
t	Measured temperature, ^oC
Δt	Temperature difference, ^oC
v	Specific volume, m^3/kg
V	Fluid velocity, m/hr
X	Lockhart & Martinelli parameter
x	Dryness fraction or quality.

Subscripts

a accelerational.

f frictional.

g gas phase.

G gas r vapor flowing alone in the tube

H homogeneous flow.

L liquid flowing alone in the tube.

l liquid phase.

m two-phase mixture.

O at stagnation.

Dimensionless groups

R_e Reynold's number.

4f The friction factor.

K Slip ratio or ratio of gas to liquid mean velocities $[V_G/V_L]$

We Dimensionless equivalent flow rate.

Greek letters

α Void fraction or fraction of volume occupied by the gas phase.

Γ^2 The ratio between total flow pressure gradient having the gas physical properties to that of the liquid physical properties.

μ Dynamic viscosity, kg/m sec.

ρ Fluid density, kg/m^3

σ Surface tension, N/m.