Process Technology Proceedings, 1

Multi-Phase Flow and Heat Transfer III

Part A: Fundamentals

Edited by

T. Nejat Veziroğlu

and

Arthur E. Bergles

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Proceedings of the Third Multi-Phase Flow and Heat Transfer Symposium — Workshop, Miami Beach, Florida, U.S.A., April 18—20, 1983

Edited by

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PART A – FUNDAMENTALS

MULTI-PHASE FLOW & HEAT TRANSFER III

PART A FUNDAMENTALS

PART B APPLICATIONS

Proceedings of the Third Multi-Phase Flow and Heat Transfer Symposium-Workshop, held in Miami Beach, Florida, U.S.A., on 18-20 April 1983, and presented by the Clean Energy Research Institute, College of Engineering, University of Miami, Coral Gables, Florida, U.S.A.; sponsored by the National Science Foundation, Washington, D.C., U.S.A.; in cooperation with the International Association for Hydrogen Energy, International Journal of Heat and Mass Transfer, and the Department of Mechanical Engineering, University of Miami, Coral Gables, Florida, U.S.A.

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We wish to extend our sincere appreciation to the Invited Speakers: Dr. Win Aung, Director, Heat Transfer Program, National Science Foundation; Dr. Adrian Bejan, Associate Professor, Department of Mechanical Engineering, University of Colorado, Boulder, Colorado; and Dr. Jack T. Sanderson, Assistant Director for Engineering, National Science Foundation. We also thank Dr. Arthur E. Bergles, Distinguished Professor, Department of Mechanical Engineering, Iowa State University, Ames, Iowa, for his efforts in organizing and directing the workshop sessions.

Special thanks are due to our authors and lecturers, who have provided the substance of the symposium as published in the present proceedings.

And last, but not least, our debt of gratitude is owed to the Session Chairpersons and Co-Chairpersons, and to the Workshop Group Leaders, for the organization and execution of the technical and workshop sessions.

The Organizing Committee
Third Multi-Phase Flow and Heat
Transfer Symposium-Workshop

FOREWORD

The Third Multi-Phase Flow and Heat Transfer Symposium-Workshop continued the tradition established by its predecessors, the Two-Phase Flow and Heat Transfer Symposium-Workshop of October 1976 and the Second Multi-Phase Flow and Heat Transfer Symposium-Workshop of April 1979. It provided an event worthy of this important topic, including the latest information on the status of multi-phase flow and heat transfer research, development and applications. It also sought to identify important areas of multi-phase flow and heat transfer in urgent need of further research and development. In keeping with this latter objective, workshop discussions were held among the 188 attendees who represented universities, research establishments and industrial organizations. The Workshop Summaries are presented in a separate report.

It is particularly significant that this Third Symposium-Workshop included participants from 28 countries. This assured the international character of the information transfer, in keeping with the widespread need for better understanding of the behavior of multi-phase flows.

This two-volume set of proceedings includes 119 papers from the Symposium program. The great majority of the papers addresses gas-liquid flow; however, studies of gas-solid and liquid-solid flows are also included. While the heat transfer papers stress boiling (evaporation) or condensation, several papers consider phase change via freezing or melting. The papers have been divided into those that relate to fundamentals (Part A) and those that emphasize applications (Part B).

Included in Part A are papers dealing with the formulation of the multi-phase flow equations and solutions of these equations, flow regime transitions for gas-liquid flows, flow structure details and pressure drop of gas-liquid flows, steam separation and distribution, pressure wave propagation in gas-liquid and gas-solid flows, flashing and critical flow, heat transfer in pool boiling and forced convection boiling, heat transfer in dispersed gas-liquid flows, heat transfer in condensing, and thermal hydraulic instabilities.

Part B includes a large collection of papers addressing safety issues in nuclear reactor technology: thermal hydraulic code development, experiments to assess performance and validate codes and modelling of selected accident phenomena. Other papers in this part consider gas-solid flows, fluidized beds, liquid-solid flows, freezing and melting, mass transfer and chemical reactions, porous media, measurement techniques, and miscellaneous industrial applications.

The papers included in these two volumes are of both current and archival interest. The volumes should, therefore, serve as both a proceedings of the Symposium-Workshop and as a reference covering important topics in the field of multi-phase flow and heat transfer.

T. Nejat Veziroḡlu
Arthur E. Bergles

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Co-Chairperson:	S. C. Yao, Carnegie-Mellon University, Pittsburgh, Pennsylvania, U.S.A.
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Workshop Leader:	J. Lienhard, University of Houston, Houston, Texas, U.S.A.
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Chairperson:	T. M. Romberg, CSIRO Division of Mineral Physics, Sutherland, NSW, Australia
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Chairperson:	T. W. Fogwell, Texas A & M University, College Station, Texas, U.S.A.
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Chairperson:	A. E. Bergles, Iowa State University, Ames, Iowa, U.S.A.

PART A — FUNDAMENTALS

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SECOND-LAW ASPECTS OF HEAT TRANSFER ENGINEERING

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ABSTRACT

Used together, the first and second laws of thermodynamics indicate that any engineering device destroys available (useful) work at a rate proportional to its rate of entropy generation. Heat exchange apparatuses always generate entropy, due to the inherent irreversibility of heat transfer across a finite temperature difference and due to the irreversibility of fluid flow against resistive friction forces. On thermodynamic grounds, then, in this lecture it, is argued that the design philosophy that insures the conservation of available work ("useful energy") is the Minimization of Entropy Generation in the design of heat exchange devices and in the design of components and subcomponents for such devices. The ability to optimally select the geometry of a device such that its entropy generation rate is minimized, is illustrated based on examples drawn from duct design, fin design and heat exchanger design.

1. INTRODUCTION

I want to thank the organizers for the invitation to present this lecture at the Third Multi-Phase Flow and Heat Transfer Symposium-Workshop. I feel very honored by this invitation.

In this lecture I will rely on the classical statements of the first and second laws of thermodynamics to show the intimate connection between heat transfer processes and the destruction of available work in installations that employ heat transfer processes. I will then argue that one design philosophy that insures the reduction of available work destruction (i.e. the conservation of "useful" energy) is the minimization of entropy generation in each of the components of an engineering installation [1,2]. Finally, I will illustrate this design philosophy by means of examples ranging from the design of individual fins to that of heat exchangers processing two-phase streams.

2. THE NEED TO MINIMIZE ENTROPY GENERATION

Consider the steady (cyclic) operation of a power plant, as shown schematically in Fig. 1. The power plant receives its heat input at a rate $\dot{Q}_H$ from a high temperature reservoir of absolute temperature T_H. Shaft work is being produced at a rate $\dot{W}$, and heat is being rejected at a rate $\dot{Q}_L$ to a low temperature reservoir T_L. The first and second laws of thermodynamics for the power plant as a thermodynamic system, state that [3]