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ANNOUNCEMENT

MULTIPHASE FLOW AND HEAT TRANSFER: BASES, MODELING AND APPLICATIONS

A 5-DAY WORKSHOP

Hosted by
Department of Chemical and Nuclear Engineering, The University of California, Santa Barbara, U.S.A.

27 September–2 October 1992

THE PROGRAM

Two-phase flow and boiling heat transfer continue to focus the attention of researchers and to frustrate and challenge the engineer in the chemical, nuclear, oil-and-gas, cryogenic and other industries. New data and information, ideas and hypotheses, and facts and erroneous theories continue to be produced.

The short course described here is patterned after similar courses offered for a number of years at Stanford University and more recently at the University of California—Santa Barbara and at ETH—Zurich. Its intent is to provide:

- A condensed and critical view of present knowledge including areas of uncertainty.
- Transfer of knowledge from one area of application to another.
- Sources of data and correlations.
- System analysis and design philosophy and methods.
- Limitations of modern codes will be pointed out.

The course features:

- A program of coordinated lectures by experts in the field.
- A complete set of lecture notes and copies of slides.
- Movies to illustrate physical phenomena.
- Limited enrollment.

Course Directors
G. Hetsroni and S. Banerjee.

The Lecturers

Sanjoy Banerjee is Professor at the Department of Chemical and Nuclear Engineering, University of California—Santa Barbara. Previously in Canada, he occupied the positions of Westinghouse Professor of Engineering Physics at McMaster University and of Acting Director of Applied Science in the Whiteshell Nuclear Research Establishment. He was a founding member of the Canadian Advisory Committee on Nuclear Safety and serves as a consultant to governmental and industrial organizations in several countries. He was also a Visiting Professor at the Swiss Federal Institute of Technology in Zurich (ETHZ). He is a member of several editorial boards, and has served as Chair of the American Nuclear Society Thermal Hydraulics Division.

Gad Hetsroni is Dançiger Professor of Engineering at Technion—Israel Institute of Technology. He is also a Visiting Professor, University of California—Santa Barbara. He has occupied positions at Westinghouse EPRI and Stanford University in the U.S.A. He has also served as Director of the National Council for Research and Development in Israel, and as Dean of the Faculty of Mechanical Engineering at Technion. He has worked on many different aspects of two-phase flow and is the founder and Editor of the *Int. J. Multiphase Flow* and Editor of the *Handbook of Multiphase Systems*. He is a Fellow of the American Society of Mechanical Engineers.

Geoffrey F. Hewitt is Professor of Chemical Engineering at Imperial College London. He was formerly head of the Thermal Hydraulics Division and founder of the Heat Transfer and Fluid Flow Service (HTFS) at the Harwell Laboratory, England. Professor Hewitt has authored and edited many books on heat transfer and

fluid flow and published over 150 papers and reports, mainly on gas–liquid flow and evaporative heat transfer. He is Editor of a number of journals including *Experimental Heat Transfer*, *Transactions of the Institution of Chemical Engineers* and Associate Editor of the *Int. J. Multiphase Flow*. Professor Hewitt was the 1989/90 President of the Institution of Chemical Engineers and, in 1989, was elected a Fellow of the Royal Society.

Salomen Levy is the President of S. Levy Incorporated, a consulting firm to the power industry. Prior to assuming that position in 1977, he was associated with the nuclear business of General Electric in various management positions, including being in charge of all the engineering and manufacturing of their boiling water reactors. Dr Levy is a member of several oversight and safety committees of nuclear power plants. He is a member of the National Academy of Engineering, a Fellow of the American Nuclear Society and American Society of Mechanical Engineers. He is a Director of IE Industries.

George Yadigaroglu is Professor of Nuclear Engineering at the Swiss Federal Institute of Technology in Zurich (ETHZ). He is also heading the Thermal-Hydraulics Laboratory at the Paul-Scherrer Institute (formerly EIR). He was previously Professor of Nuclear Engineering at the University of California—Berkeley, and from 1979 until 1982 he served as Head of the Nuclear Regulatory Service of the Greek Atomic Energy Commission. He has done research and has actively consulted for various organizations and national laboratories on a range of two-phase flow and heat transfer topics. He is a member of the editorial board of *Experimental Heat Transfer* and Associate Editor of the *Int. J. Multiphase Flow*. He is a Fellow of the American Society of Mechanical Engineers.

CONTENTS OF THE LECTURES

Monday, 28 September

1. **Introduction and Basics:** *G. Hetsroni.* Nature of multiphase flows. Definition of basic quantities. Basic concepts of control volume averaging. Homogeneous and mixture models.
2. **Basic Equations:** *S. Banerjee.* Averaging and derivation of conservation equations. Time and space dependent effects. Virtual mass. Multifluid models. Drift flux model. Requirements for closure relationships.
3. **Flow Regimes, Pressure Drop and Void Fraction:** *G. Hetsroni.* Description of flow regimes. Flow regime maps. Analytical bases for the flow regime transitions. Pressure drop and void fraction in various flow regimes.
4. **Phenomenological Modeling: Continuous Flow:** *G. F. Hewitt.* Bubble flow: drift flux correlations, void profile, turbulence, coalescence. Stratified flow: simple and more advanced models, turbulence. Annular flow: basic theory, entrainment and deposition, modeling, applications.

Tuesday, 29 September

5. **Phenomenological Modeling: Intermittent Flow:** *G. F. Hewitt.* Plug flow: bubble rise velocity, mechanisms, stability. Churn flow: mechanisms, interpretations, modeling. Slug flow: fluid behaviors in slugs, slug frequency and velocity.
6. **Closure Relationships:** *G. Yadigaroglu.* Interfacial area. Wall and interface friction. Relationships between void fraction and interfacial friction. Interfacial heat transfer. Empirical closure laws.
7. **Two-phase Heat Transfer:** *G. Hetsroni.* Boiling heat transfer: nucleate boiling, forced convection. Correlations and models. Dryout (critical) heat flux: mechanism and prediction.
8. **Post-dryout Heat Transfer and Rewetting:** *G. Yadigaroglu.* Description of physical phenomena: importance of departures from mechanical and thermal equilibrium. Dispersed flow film boiling: drop size spectrum and distributions. Various types of rewetting phenomena.

Wednesday, 30 September

9. **Numerical Methods:** *S. Banerjee.* Initial and boundary conditions. Method of characteristics. Finite difference methods. Stability. Explicit and implicit methods. Methods used in computer codes.
10. **Flow Limiting Phenomena:** *G. Yadigaroglu.* Critical two-phase flow: basic concepts, difficulties in calculating flow rate due to the nature of two-phase flow. Countercurrent-flow limitations: the flooding mechanisms, models, correlations; importance of geometry and subcooling.
11. **Multidimensional Modelling:** *S. Banerjee.* Basic multidimensional equations. Direct simulation. Large eddy simulation. Turbulence modeling: three-dimensional effects.
12. **Instabilities in two-phase flow:** *G. Yadigaroglu.* Instabilities of the liquid–gas interface. Modes of system instability: fundamentals, mechanisms. The Ledinegg instability, flow distribution instabilities, density wave oscillations etc. Analytical tools, stability maps, BWR stability.

Thursday, 1 October

13. **Computer Codes:** *G. F. Hewitt.* Generic approach in computer codes. Specific coes (RELAP, TRAC FLOW3D, PHOENICS, etc.). Achievements and limitations of codes. Future development and applications in nuclear systems.
14. **Two-phase Phenomena in Advanced Reactors:** *S. Levy.* Key phenomena associated with design of advanced water reactors. Special features arising from evolutions in design. Containment and passive safety aspects.
15. **Condensation Phenomena:** *G. F. Hewitt.* Modes of condensation. Interfacial resistance. Film condensation: gravity controlled and shear controlled. Spray condensation.
16. **Steam Generators:** *G. Hestroni.* Nuclear steam generators. Design considerations. Operational problems: corrosion, vibration etc. Extension of lifetime. Alleviation of problems. New design concepts and replacement.

Friday, 2 October

17. **Severe Accidents:** *G. Yadigaroglu.* Severe accident scenario and phenomena. Vapour explosions. Debris-bed cooling etc.
18. **Space and Microgravity Applications:** *S. Banerjee.* Two-phase phenomena in microgravity environment: heat transfer and flow regimes. Space boiling and condensation systems.

REGISTRATION INFORMATION

Registration is requested by **1 September 1992.** To request space after this date call (805) 893-4993. No refunds will be granted after this date unless the workshop is cancelled. To secure registration, send registration form plus payment prior to **1 September.**

WORKSHOP FEES

Registration fees are $1150 (U.S.) and include lecture notes, copies of all slide notes, reception and workshop banquet. The lectures will be conducted at the Sheraton. Because of space limitations, participants are urged to register well before the deadline.

HOTEL INFORMATION

Participants may stay at the Sheraton Santa Barbara at a special room rate of $89/night. Please contact the hotel directly [*Tel*: (805) 963-0744 or *Fax*: (805) 962-0985] and mention the workshop.

FOR FURTHER INFORMATION CALL:

Jessica, *Assistant to Professor Banerjee*
***Tel:* (805) 893-4993**
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