MULTIPHASE FLOW
AND HEAT TRANSFER

Fourth International Symposium
August 22-24, 1999
Xi'an China

Edited by

Xue-jun Chen, Ting-kuan Chen, Zhong-qi Chen

The State Key Laboratory of Multiphase Flow in Power Engineering, Xi'an Jiaotong University
Xi'an, 710049, China

Xi'an Jiaotong University Press
Xi'an China
CONTENTS

KEYNOTE PAPERS

K01 Dynamic Simulations of Pressure-Drop Type Instabilities in a Two-Phase Upflow Boiling System Including the Modeling of the Exit Restriction
Li-ping CAO, Sadik Kakac, Hong-tan LIU .................................................. 1

K02 Flow Instabilities and Transient Convective Heat Transfer in a Helical Coiled Tube with Pulsatile Steam-Water Two Phase Flow
Xue-jun CHEN, Lie-jin GUO ................................................................. 14

K03 Recent Work on Multiphase Flow with Phase-Change Heat Transfer Capillary Structures
P. CHENG, T. S. ZHAO ................................................................. 37

K04 The Use of Electric Fields to Enhance Two-Phase Heat Transfer
Tassons G. KARAYIANNIS .......................................................... 53

K05 Oil-Water Distributions in Large Diameter Horizontal Pipelines
Hua SHI, J. Y. CAI, W. P. JEPSON .................................................. 73

K06 An Analogy between Heat and Mass Transfer through an Analysis of Heat and Water Vapor Exchange Using a Total Heat Exchanger
Osamu TANAKA ................................................................. 81

K07 Multiscale Treatment of Multiphase Flow
T.G. THEOFANOUS ................................................................. 92

PART A. MULTI-PHASE FLOW FUNDAMENTALS

A01 A Critical Evaluation of Models for Turbulent Film Condensation on a Vertical Flat Plate
Adrian BRIGGS ................................................................. 100

A02 Numerical Modeling for Pigging Operations in Oil and Gas Two-Phase Flow Pipelines
Zhi-peng LIANG, Yan-peng WANG, Zong-hu LIN ..................................... 108
A03  A Mechanistic Model of Critical Heat Flux for Subcooled Water in a Wide Parametric Range
Yu-jun GUO, Kaichiro MISHIMA .................................................. 117

A04  Predicting CHF Using Artificial Neural Network
Gang XIAO, Guang-hui SU, Rui-lan Liu, Dou-nan JIA ...................... 125

A05  Bifurcation Phenomenon of Two-Phase Natural Circulation System
Wei YAO, Bo KUANG, Ji-jun XU .................................................. 130

A06  Liquid Contact Area Fraction Model for CHF Prediction in Annulus at High Vapor Quality
Sung-deok HONG, Se-young CHUN, Sun-kyu YANG, Moon-ki CHUNG, Cheol PARK .................................................. 138

A07  Nonlinear Analysis of Pressure Fluctuation of Air-Water Two-Phase Flow
Bo-feng BAI, Lie-jin GUO .......................................................... 148

A08  Investigation of the Nonlinear Behavior of Pressure Fluctuation in Liquid-Gas Two-Phase Flow
Jing WANG, Ju-cao LIANG ....................................................... 156

A09  An Investigation on the Velocity of TAYLOR Bubble in Upward Inclined Slug Flow
Guo-dong XIA, Fang-de ZHOU, Ming-sheng HU ......................... 164

A10  Application of the Electrochemical Method to the Study of Transport Phenomena in Two-Phase Flow System
Ping-wen MING, Zi-qiu SHEN .................................................. 172

A11  Effects of Vapor Phase on Boiling Heat Transfer
Zhong-ning SUN, Chang-qi YAN, Ze DU .................................... 180

A12  Two-Phase Flow Pattern and Pressure Fluctuation of Two-Phase Upward Flow in a U-type Tube
Bo-feng BAI, Tie-jun WU, Liejin GUO, Xi-min ZHANG .................. 187

A13  Slug Frequency and Length in Inclined Large Diameter Multiphase Pipeline
J.Y.CAI, H.W. WANG, T.HONG, W.P. JEPSON ............................. 195

A14  Numerical Simulation of Gas-Solid Flow in Different Tunnels
Jin XU, Man-chu GE .............................................................. 203
<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Authors</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A15</td>
<td>Fractal Characteristics Investigation on Subcooled Boiling in Pipe and Its Application</td>
<td>Bo KUANG, Ji-jun XU, Fang-zhou GUO</td>
<td>210</td>
</tr>
<tr>
<td>A16</td>
<td>Thermo-Hydraulic Analysis of Water-Heated Once-Through Steam Generator</td>
<td>Hai-jun JIA, Chul-hwa SONG, Suk-k.SIM, Huai-ming JU</td>
<td>218</td>
</tr>
<tr>
<td>A17</td>
<td>Identifying Flow Regime of Oil/Gas/Water Multiphase Flow with Neural Network</td>
<td>Hao-jiang WU, Zheng-min CAI, Fang-de ZHOU</td>
<td>226</td>
</tr>
<tr>
<td>A18</td>
<td>Numerical Analysis of Two-Phase Flow around a Horizontal Tubes in Nucleate Boiling</td>
<td>Qiang BAI, Yasunobu FUJITA</td>
<td>234</td>
</tr>
<tr>
<td>A19</td>
<td>Measurement of Void Fraction Using a Vertical Ventury in Upward Two Phase Flow</td>
<td>Qiang YE, Ting-kuan CHEN, Yu-shan LUO</td>
<td>242</td>
</tr>
<tr>
<td>A20</td>
<td>CFD Study of Droplet Motion in a Simplified Breather Chamber Geometry at High Shaft Rotating Speed</td>
<td>Yi WANG, I CARE, C EASTWICK, S HIBBERD K SIMMONS</td>
<td>250</td>
</tr>
</tbody>
</table>

PART B. GAS-LIQUID TWO-PHASE FLOW

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Authors</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>B01</td>
<td>Re-Entrainment in Horizontal Wave-Plate Demisters</td>
<td>K SANAULLAH, B J AZZOPARDI</td>
<td>258</td>
</tr>
<tr>
<td>B02</td>
<td>On Safety of Water Wall of Large Hypo-Critical Pressure Boilers with Natural Water Circulation</td>
<td>Jun-kai FENG</td>
<td>266</td>
</tr>
<tr>
<td>B03</td>
<td>Unsteady-State Boiling Heat Transfer from an Aluminum Cylinder to a Ferrofluid</td>
<td>Li-zhi LIU, Guo-dong XIA, Chong-fang MA</td>
<td>271</td>
</tr>
<tr>
<td>B04</td>
<td>Blockage of Beams Considerations for LDA and PDA Measurements in Dispersed Two Phase Flows</td>
<td>Thrasyvoulos PANIDIS, Zi-ping FENG, Georgios FILIS, Dimitris PANAGIOTOPoulos</td>
<td>277</td>
</tr>
</tbody>
</table>
B05 Study on Hydrodynamic Characteristics of Oil-Water Two-Phase Emulsion under the Disturbance of Gas in Vertical Upward Tubes
Yue-she Wang, Yuan-wei LU, Fang-de ZHOU 287

B06 Experimental Investigation of Boiling in Rectangular Narrow Space
Rong-hua Zhang, Song-yu LIU, Bo KUANG, Ji-jun XU 295

B07 An Analytical Study of Critical Heat Flux in a Narrow Gap
Zhi-lin YANG, Truc-Nam DINH, Bal-Raj SEHGAL 302

B08 The Frictional Pressure Drop of Steam-Water Two-Phase Flow during Forced Convective Boiling inside a Small Horizontal Helical Coil Tube
Liang ZHAO, Yu-cheng HOU, Lie-jin GUO, Guang-jun LI, Xi-min ZHANG 310

B09 Boiling in a Horizontal Three Dimensional Microfin Tube for R134a
Jie ZHOU, Qing-hua CHEN, Ming-dao XIN, Gang ZHANG 318

B10 Study of Upward Two-Phase Flow Frictional Pressure Drop in Vertical Tubes
Li-xin CHENG, Ting-kuan CHEN 326

B11 Study of Three-Dimensional Two-Phase Flow in Horizontal Heated Tube Bundles
Rui-chang YANG, Rong-chuan ZHENG, Yan-wu WANG, Li-jia ZHOU 334

B12 Theory and Application of Ultrasonic Cross Correlation Flowmeter for Oil-Water Flow
Zhi-hui WANG, Lei WANG 342

B13 Critical Heat Flux during Natural Circulation Boiling on Uniformly Heated Outer Tube in Vertical Annular Tubes Submerged in Saturated Liquid (Change in CHF Characteristics due to Heated Equivalent Diameter)
Masanori MONDE, Yuichi MITSUTAKE 348

B14 Investigation of Different Types of Two-Phase Flow Instability in Parallel Boiling Channels under High Pressure
Min XIAO, Xue-jun CHEN, Ming-yuan ZHANG 356
B15 Experimental Research and Data Processing on Regularity of Multiphase Flow Patterns in Inclined Pipes
Xiu-shan LIU, Zai-hong SHI, De-zhu LIU, Shu-shan HE .......................... 364

B16 An Experimental Investigation of Flow Patterns in Oil-Water Two-Phase Flow through Coiled Tubes
Guang-jun LI, Lie-jin GUO, Xue-jun CHEN,
Hui GAO, Li-jun YU ................................................................. 372

B17 Critical Heat Flux in Non-Uniformly Heated Vertical Annulus under a Wide Range of Pressures
M.K. CHUNG ............................................................................. 380

B18 An Experimental Study of Co-Current Two-Phase Flow Patterns in Small Triangular Channels
Q. C. BI, T. S. ZHAO, P. CHENG .................................................. 388

B19 The Measurement of the Wetness of Flowing Wet Steam by a New Heating Method
Yan-feng LI, Xin-jun WANG, Ting-xiang XU,
Jun-mei LI, Heng JIA ................................................................. 394

B20 Sensitivity Analysis of 600MW Supercritical Pressure Once-Through Boiler
Jin-tao HUANG, Ting-kuan CHEN ................................................. 403

PART C. GAS-SOLID TWO-PHASE FLOW

C01 Propagation of Acoustic Wave in a Screen of Dusty Gas
Evgeny S. ASMOLOV .................................................................. 410

C02 An Experimental Study on the Hot Flying-ash Erosion of Common Steel Materiel for Coal-Fired Boiler in Power Stations
Xian-ping ZHAO, Jian-rong SUN, Jia-qing SUN ............................. 418

C03 The Exit Effect on Hydrodynamics of Gas-Solid Two-Phase Flow in Circulating Fluidized Bed Boilers
Xiang-yang LI, Xu-yi ZHANG ....................................................... 425

C04 Solid Suspension Density Distribution in the Furnace of 75t/h Circulating Fluidized Bed Boiler with Water-Cooled Square Separator

XI
PART D. NUCLEAR REACTOR SAFETY

D01 Effect of Oxidation and Precursory Cooling on Quenching of Hot Surfaces
Alon DAVIDY, Ezra ELIAS, Shmuel OLEK ........................................ 495

D02 Application of Melsim to the Studying of PWR Severe Accidents
Gang TANG, Sen-ru ZHANG, Guang-ming JIANG ............................. 503

D03 Fragmentation Behavior of Melt Drops in Coolant: Effects of Melt Fusion Heat and Mushy Zone
Huixiong LI, T.N. DINH, H.O. HARALDSSON, B.R. SEHGAL ................................................................. 511

D04 Core Makeup Tank Behavior Study for AC-600
Xiao-hua FU ................................................................. 519

D05 Analytical Study of Coolability of Ex-vessel Debris Beds with Downcomer(s)
Guang-jun LI, Zhi-lin YANG, Hui-xiong LI, Bal-Raj SEHGAL ................................................................. 525

D06 Verification of CATHARE2 V1.5QR6 using the Experimental Data of BETHSY Natural Circulation Tests
Yan-ping HUANG, I.DOR, D.BESTION B.FAYDIDE ......................... 533

D07 The Theoretical Analysis of Natural Circulation of Integrated Nuclear Power System
Guang-hui SU, Dou-nan JIA ................................................................. 541

D08 Boiling Induced Mixed Convection for a Passive Cooling System
Greet JANSSENS-MAENHOUT, Markus DAUBNER, Joachim KNEBEL, Ulrich MüLLER ................................................................. 547

D09 Flow Excursion in Natural Circulation System
Sheng-yao JIANG, You-jie ZHANG, Xin-xin WU, Jin-hai BO, Zhi-yong LIU, Hai-jun JIA ................................................................. 555

D10 Numerical Simulation of the Deformation and Breakup Behavior of Droplets in Multiphase Systems: Applications of the Level Set Method
Hui-xiong LI, Ting-kuan CHEN, V. A. BUI, T. N. DINH, B. R. SEHGAL ................................................................. 563

D11 Validation of the Cathare2 V1.5 Revision6 Code for Nuclear Safety
G.GEFFRAYE, B.BRUN ................................................................. 571

PART E. APPLICATIONS

E01 Analysis for Effect of Gas Expansion on Monitoring Leakage in Multiphase Pipeline
Lei LIU, Stuart L SCOTT ................................................................. 579

E02 Comparison of the SIMPLE-Like Algorithm for Solving Pressure-Velocity Coupling Equations in Steady Flow Problems
E03 Research of Heat Transfer in the Compact Heat Exchanger Working on Twophase Heat Carriers
Yuriy V. DJACHENKO, Alexander V. CHICHINDAEV  595

E04 Analysis and Experiment of Pressure Drops in Twist, Turn and Orifice Streams
Jun-liang CHEN, Shi-tou SHEN, Hui-ping CHENG, Xian-yuan WANG  603

E05 The Heat Transfer of Cryogenic Two Phase Fluid in Narrow Channel and the Progress of Research for Plate-Fin Condenser-Evaporator
Liu-fang CHEN, Yu-yuan WU, Shu-feng SUN, Rui ZHANG  608

E06 Research on Application for Heat Exchanger Using Two Phase Thermosyphons with Two Cooling Sections and Its Reflux Condensation Heat Transfer
Gamal M.GHARSSA, Ya-cai HU, Muftah A. ABURGHAIA, Adel M. SHAPO, Chuan-jing TU  615

E07 Experimental and Theoretical Analysis on Condensation Heat Transfer Enhancement of a New Spiral Finned Tube
Ping LIANG, Xin-feng LONG, Li-xian ZUANG, Ying-ke TAN  623

E08 Numerical Prediction of the Heat Transfer Performance of Large Power Plant Condensers
Guang-yu ZHU, Mao-zheng YU, Hong-mei LI, Xiu-ping YAO  631

E09 Fabrication and Test Result of Cooling Machine for Low Temperature Ice Crystals and Aqueous Solution Mixture Flow
T.HARUYAMA, T.KONDO, N.UNNO, S.TERADA, T.KOHRIKI  640

E10 Experimental Studies for EHD Boiling Heat Transfer Enhancement on a Tube Bundle
Xuan HUANG, Rui-yang LI, Hong-ling YU, Zhi-hang CHEN, En-ke AN  646

<table>
<thead>
<tr>
<th>Title</th>
<th>Authors</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>E12 Numerical Simulation and Experimental Research of the Fluid Field and Temperature Field of Inner Natural Circulation in CO Quick Freezer</td>
<td>Yao-jun LU, Li-xing ZHOU, Xiong SHEN</td>
<td>654</td>
</tr>
<tr>
<td>E13 Heat Transfer in Two Phase Flow of Solid and Liquid Foods</td>
<td>Zheng-liang TAO, Rui QIAN, Kang-min CHEN</td>
<td>664</td>
</tr>
<tr>
<td>E14 Experimental Investigation on Single-Phase Convection Heat Transfer in Annular Gap</td>
<td>Tian-qing LIU, Xiang-yu SUN, Jia-bin CHEN</td>
<td>672</td>
</tr>
<tr>
<td>E15 Analytical Method in Inverse Heat Transfer Problem Using Laplace Transform Technique</td>
<td>Li-shuo LI</td>
<td></td>
</tr>
<tr>
<td>E18 Calculation Approach of Hydraulic Parameters of the Motionless Mixer Combining Swirl and Division</td>
<td>Chuan-ting LIN</td>
<td>702</td>
</tr>
<tr>
<td>E19 Research on Condensation Heat Transfer inside an Annular Horizontal Tube</td>
<td>Muftah A. ABURGHAIA, Ya-cai HU, Gamal M. GHARSSA, Adel M. SHAPO, Chuan-ting TU</td>
<td>713</td>
</tr>
<tr>
<td>E20 Heat Transfer Enhancement with Air-Droplets Flow</td>
<td>Viktor I. TEREKHOV, Alexander V. CHICHINDAEV</td>
<td></td>
</tr>
</tbody>
</table>
Maxim A. PAKHOMOV ................................................................. 720

E21 An Improved Correlation for Forced Condensation Heat Transfer of
R-134a in Horizontal Tubes
Pei-wen LI, Hua-sheng WANG, Min CHEN, Wen-quan TAO ........ 727

E22 Forced Convection Triangular Ducts with Uniformly Spaced
Rectangular Ribs
S.CHEN, T.L.CHAN, C.W.LEUAG ............................................. 736

E23 Radiation Calculations in Furnace Using
Smoothing Monte Carlo Method
M.S.LIU, C.K.CHOI, C.W.LEUNG .............................................. 745

E24 A Study on the Characteristics of the Heat Transfer,
Combustion Emission and Noise in a Compact Boiler
without the Extra Zone for Fuel Gas Combustion
Hyouck-ju KIM, Byung-sik PARK
Jong-jin KIM, Duc-hwan KIM ................................................. 754

Author Index ................................................................. 762