Eighth International Topical Meeting on Nuclear Reactor Thermal-Hydraulics

NURETH-8

New Horizons in Nuclear Reactor Thermal-Hydraulics

Volume 2

September 30 - October 4, 1997

Kyoto, Japan

Sponsored by
Atomic Energy Society of Japan (AESJ)
Thermal-Hydraulics Division of American Nuclear Society (ANS/THD)
ANS Japan Section

Co-Sponsored by
Japan Atomic Energy Research Institute (JAERI)
Power Reactor and Nuclear Fuel Development Corporation (PNC)
Nuclear Power Engineering Center (NUPEC)
British Nuclear Energy Society (BNES)
Canadian Nuclear Society (CNS)
Korean Nuclear Society (KNS)
Taiwan Chung-Hwa Nuclear Society
American Institute of Chemical Engineers (AIChE)
American Society of Mechanical Engineers (ASME)
Japan Society of Mechanical Engineers (JSME)
Institute of Electrical Engineers of Japan (IEEJ)
Japan Society of Plasma Science and Nuclear Fusion Research (ISPF)
Federation of Electric Power Companies, Japan
Japan Electrical Manufactures' Association (JEM/)

NURETH-8 was financially supported by the Ministry of Education, Science and Culture with the Grant-in-Aid for Publication of Scientific Research Result of Grant-in-Aid for Scientific Research.
# LWR In-Vessel Phenomena - I

Corium Kinematic Viscosity Measurement  
581

Experimental Investigation of Natural Convection of a Two-Component Gas in a Simplified PWR Model Primary Coolant Loop  
P. Fischer, M. Groll  
587

Experimental and Analytical Study on Aerosol Behavior in WIND Project  
A. Hidaka, Y. Maruyama, M. Igarashi, K. Hashimoto, J. Sugimoto  
595

# LWR In-Vessel Phenomena - II

VVER-440 Core Degradation Experiment  
Z. Hózer, L. Marótí, B. Tóth, P. Windberg  
605

Melt Jet Attack of the Reactor Vessel Wall: Phenomena and Prediction Method  
T.N. Dinh, W.G. Dong, J.A. Green, R.R. Nourgaliev, B.R. Sehgal  
612

The Modeling and Analysis of In-Vessel Corium/Structure Interaction in Boiling Water Reactors  
M.Z. Podowski, N. Kurul, S-W. Kim, W. Baltyn, W. Frid  
620

# LWR Fuel-Coolant Interactions

Effect of Coolant Velocity on the Fragmentation of Single Melt Drops in Water  
M.H. Cunningham, D.L. Frost  
628

Numerical Simulation of Surface Instability Phenomena Associated with Fuel-Coolant Interactions  
V.A. Bui, T.N. Dinh, B.R. Sehgal  
639

Numerical Analysis of Liquid Metal and Coolant Interaction  
X. Cao, K. Furuta, S. Kondo  
647

An Experimental Study of Fuel-Coolant Interactions in Freon-Water and Water-Molten Tin Systems in Stratified and Injection Geometries  
M. Baker, B. Shamoun, R. Bonazza, M. Corradini  
655

Effect of the Rapid Evaporation on the Motion of Melt Drops during the Coarse Mixing Process of Vapor Explosions  
Y. Yang, H. Ohashi, J. Sugimoto  
663

# CHF and Film Boiling Heat Transfer Correlations

A Look-Up Table for Film-Boiling Heat-Transfer Coefficients in Tubes with Vertical Upward Flow  
L.K.H. Leung, N. Hammouda, D.C. Groeneveld  
671

Film Boiling Heat Transfer from a Vertical Cylinder in Forced Flow of Liquids under Saturated and Subcooled Conditions at Pressures  
M. Shiotsu, K. Hama  
679

Critical Heat Flux for Vertical Annulus Flow Channel under Low Flow and High Pressure Conditions  
691

Critical Heat Flux of Water in Vertical Round Tubes at Low-Pressure and Low-Flow Conditions  
699

# LWR Low-Power Transients - I

Analysis of RWST Water Level during Mid-Loop Operation in YGN3/4  
K.D. Kim, G.S. Ha, W.S. Kim, Y.J. Chung, W.P. Chang  
709

Analysis with the CATHARE Code of a Loss of RHRS during Mid-Loop operation at the BETHSY Facility  
N. Messer, G. Lavialle, F. Barré  
717
### CATHARE Code Simulation of the BETHSY Loss of Residual Heat Removal Test
A.A. Troshko, Y.A. Hassan

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>725</td>
</tr>
</tbody>
</table>

### LWR Low-Power Transients - II
Station Blackout at Cold Shutdown Simulation with CATHARE 2 and PAREO 9 Codes
O. Weber, J.L. Chaze, M. Lotz, J.L. Vacher

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>732</td>
</tr>
</tbody>
</table>

Thermal Hydraulic Analysis of RHR Cooling during Shutdown Operation in PWR

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>740</td>
</tr>
</tbody>
</table>

Development and Assessment of the Code for Reactor Outages Thermal Hydraulic and Safety Analysis - Midloop Operation with Loss of RHR
K.-S. Liang, F.-K. Ko

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>751</td>
</tr>
</tbody>
</table>

### High-Speed Non-Equilibrium Two-Phase Flows
Critical Flow Rates of Subcooled Water Through Short Pipes with Small Diameters

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>759</td>
</tr>
</tbody>
</table>

Analysis of Film Condensation Enhancement with Porous-Layer Coated Surface
X.H. Ma, B.X. Wang

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>767</td>
</tr>
</tbody>
</table>

Extending Cavitation Models to Subcooled and Superheated Nozzle Flow
D.P. Schmidt, M.L. Corradini

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>774</td>
</tr>
</tbody>
</table>

### LWR Single-Phase Mixing Phenomena
Numerical and Experimental Study in Piping System Dead Legs
E. Deutsch, M. Barcouda, J.L. Rousset, C. Mallez

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>782</td>
</tr>
</tbody>
</table>

Computational Fluid Dynamic Analysis of a Guide Tube in a PWR
F. Hofmann, F. Archambeau, C. Chaize

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>791</td>
</tr>
</tbody>
</table>

Free Boron Plugs Mixing Transients in a 900 MW PWR Vessel: Numerical Simulation of the Accurate RCP Start-Up Transient Flow Rate
D. Alvarez, A. Martin, S. Stelletta

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>799</td>
</tr>
</tbody>
</table>

Numerical Analysis of the Mixing and Recombination in the Downcomer of an Internal Pump BWR
H. Tinoco, T. Einarsson

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>806</td>
</tr>
</tbody>
</table>

### Single-Phase Natural Circulation and Convection
Natural Convection Heat Transfer from Horizontal Rod Bundles in Liquid Sodium
K. Hata, M. Shiotsu, Y. Takeuchi, K. Hama, A. Sakurai, Y. Sagayama

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>817</td>
</tr>
</tbody>
</table>

Study on Natural Circulation Evaluation Method for a Large FBR
O. Watanabe, S. Kotake, S. Kubo, H. Kajiwara, K. Fujimata

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>828</td>
</tr>
</tbody>
</table>

Oscillatory Instability of a Single-Phase Natural Circulation Loop
T. Nishihara

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>839</td>
</tr>
</tbody>
</table>

Empirical Eigenfunction Analysis of Rayleigh-Benard Convection in Closed Cylinder
K. Hatakeyama, T. Yoshimoto, Y. Tsuji, K. Okubo, M. Tanaki, Y. Kukita

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>848</td>
</tr>
</tbody>
</table>

### Thermomechanical Transients
Thermal Fluid-Structure Interaction Analysis for the Upper Structure of LMFRs
H. Ohira

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>856</td>
</tr>
</tbody>
</table>

Evaluation Method of Check-Valve Integrity during Sudden Closure Using Thermal-Hydraulic and Structural Analyses
H. Mochizuki

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>864</td>
</tr>
</tbody>
</table>

A New Coupling of the 3D Thermal-Hydraulic Code THYC and the Thermomechanical Code CYRANO3 for PWR Calculations
S. Marguet

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>872</td>
</tr>
</tbody>
</table>

Numerical Study of a Thermal Transient in a 900 MWe Nozzle Subjected to a Severe Thermal Load
C. Péniguel, C. Mallez

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>879</td>
</tr>
</tbody>
</table>
Aging-Related Phenomena
Particle Deposition and Fouling in PWR Steam Generators
G. Srikantiah, P.R. Chappidi ................................................................. 887

Sludge Collector Performance in Steam Generators of Pressurized Water Reactor
H. Takamatsu, T. Matsunaga, R.M. Wilson, T. Kusakabe ............................. 895

Fast Reactor Transients and Accidents
Inter-Subassembly Heat Transfer during Natural Circulation Decay Heat Removal
-Experimental Transient Behavior from Forced to Natural Circulation and its Multi-Dimensional Analysis with Mixing Model-
M. Nishimura, H. Kamide, K. Hayashi, K. Momoi ..................................... 903

Experimental Investigation of the Natural Convection Heat Removal Capability of a Vessel Filled with Porous Media
H.Y. Nam, S.K. Choi, Y.B. Lee, Y.K. Kim, J.H. Cha ..................................... 914

Experimental Study of Core Thermohydraulics in Fast Reactors during Transition from Forced to Natural Circulation -Influence of Inter-Wrapper Flow-
H. Kamide, K. Hayashi, K. Momoi .......................................................... 922

Unsteady Laminar Forced Convection Heat Transfer due to Rapid Decrease in Flow Rate of Liquid Sodium in a Concentric Annulus
Y. Takeuchi, K. Hata, M. Shiotsu, A. Sakurai, Y. Sagayama .......................... 932

Plenary Lecture 3
Advanced Researches of Thermal-Hydraulics under High Heat Load in Fusion Reactors
S. Toda ................................................................................................. 942

Subcooled Boiling CHF
Critical Heat Flux with Subcooled Boiling of Water at Low Pressure
Y. Chen, R. Zhou, L. Hao, H. Chen ............................................................. 958

Critical Heat Flux in Circular Tube Geometries Using FREON-12
X. Cheng, F.J. Erbacher, F.G. Pang, U. Müller .......................................... 965

A New Mechanistic Model of Critical Heat Flux in Forced-Convection Subcooled Boiling
A. Alajbegovic, N. Kurul, M.Z. Podowski, D.A. Drew, R.T. Lahey, Jr. ........... 973

A New CHF Correlation for Flow Boiling of Water in Subcooled and Quality Regions
Z.J. Deng, T.J. Dougherty, B.W. Yang ...................................................... 981

KeyNote Lectures 3 and 4
Mechanisms of Transitions to Film Boiling in Subcooled and Pressurized Liquids due to Steady and Increasing Heat Inputs
A. Sakurai ............................................................................................. 989

Formation and Wetting of Dry Regions on Heated Walls by a Thin Liquid Film
S.G. Bankoff .......................................................................................... 1019

Transient CHF
Premature Dryout due to Flow Oscillation in Upward/Downward Flow
H. Umekawa, M. Ozawa, T. Mitsunaga, K. Mishima, T. Hibiki, Y. Saito .......... 1031

Photographic Study on Transitions from Non-Boiling and Nucleate Boiling Regimes to Film Boiling due to Increasing Heat Inputs in Liquid Nitrogen and Water
A. Sakurai, M. Shiotsu, K. Hata, K. Fukuda ............................................. 1038

Effect of Surface Conditions on Transient Critical Heat Fluxes for a Horizontal Cylinder in a Pool of Water at Pressures due to Exponentially Increasing Heat Inputs
K. Fukuda, M. Shiotsu, A. Sakurai ........................................................... 1050
### Passive LWR Designs

**Experimental and Numerical Simulation of Passive Decay Heat Removal by Sump Cooling After Core Melt Down**  

**Nuclear Heating Reactor - A Passive Advanced Light Water Reactor**  
D. Wang, Z. Zhang, Z. Gao ............................................................ 1067

**Advantage of Modified JAERI Passive Safety Reactor (JPSR-II)**  
Y. Murao, M. Ochiai ................................................................. 1074

**Alternative Startup Procedures for a PIUS-Type Reactor**  
T. Ito, K. Oyamatsu, Y. Tsuji, M. Tamaki, Y. Kukita ................................................................. 1086

### Advanced Reactor Components

**Study on Two-Phase Heat Transfer Coefficients in Helical Coil Steam Generator of 200 MW HTGR**  
Q.C. Bi, T.K. Chen, Y.S. Tian, X.J. Chen ................................................................. 1095

**Conceptual Design of a Potassium Turbine System for Transportable Reactor**  
K. Haga, H. Seino, H. Kataoka, A. Otsubo ................................................................. 1101

**Study on Two-Phase Flow Dynamics in Steam Injectors**  
T. Narabayashi, W. Mizumachi, M. Mori ................................................................. 1111

**Experiments on Advanced Concepts of IHX-SG Combined System for Loop-Type LMFBRs**  
M. Saito, T. Utida, S. Sasaguri, A. Nezu, Y. Fujii-e ................................................................. 1119

### Discussion Session 2: Coupled Fluid-Structure Vibrations in Nuclear Reactors

**Numerical Simulation and Water Experiment of Flow Induced Vibration of a Thermocouple Well**  
A. Yamaguchi ................................................................. 1130

**On Recent Studies about Gas-Liquid Two-Phase Flow Induced Vibration in PWR Steam Generator**  
T. Nakamura ................................................................. 1132

### LWR Accident Management Measures

**Modelling of Emergency Operating Procedures for VVER-440-Type Reactors**  
J. Bánáti, Gy. Ézsö ................................................................. 1134

**Thermal-Hydraulic Behavior of a PWR under Accident Conditions: Complementary Test Results from UPTF and PKL**  
K. Umminger, J. Liebert, W. Kastner ................................................................. 1142

**Experimental Evaluation of Emergency Operating Procedures on Multiple Steam Generator Tube Rupture in INER Integral System Test Facility**  

**Experiment and Analyses on Intentional Secondary-Side Depressurization during PWR Small Break LOCA (Effects of Depressurization Rate and Break Area on Core Liquid Level Behavior)**  
H. Asaka, I. Ohtsu, Y. Anoda, Y. Kukita ................................................................. 1161

### LWR System Integral Experiments

**RELAP5 Code Assessments of RD-14 Experiments in a CANDU Reactor**  
S. Lee, C.Y. Yang, I.G. Kim, Y.J. Cho, J.I. Lee ................................................................. 1169

**Investigation of Steam Generator Tube Rupture at the INER Integral System Test (IIST) Facility**  

**Validation of the APROS Thermal-Hydraulics Against the PACTEL Test Facility**  
H.R. Plit, K. Porkholm, M. Hänninen ................................................................. 1187

**Qualitative and Quantitative Analysis of CATHARE2 Code Results of Counterpart Tests Calculations in LOBI, SPES, BETHSY, LSTF Facilities**  
F. D’Auria, M. Ingegneri ................................................................. 1195
<table>
<thead>
<tr>
<th>Title</th>
<th>Authors</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>RBMK-1500 Downcomer LOCA Analysis Using State-of-the-Art Codes</td>
<td>E. Uspuras, A. Kaliatka, K. Almenas</td>
<td>1220</td>
</tr>
<tr>
<td>Analysis of a Loss-of-Heat-Sink under Severe Accident Conditions with a New Developed Method of Combined Linking of RELAP5, COSBWR and HECHAN 3.1</td>
<td>Z. Stosic</td>
<td>1228</td>
</tr>
<tr>
<td>Validation of a RELAP5 Computer Model for a VVER-1000 Nuclear Power Plant</td>
<td>P. Groudev, P. Konstantinov, W. Shier, G. Slovik</td>
<td>1241</td>
</tr>
</tbody>
</table>