

# **Asian Nuclear Prospects 2010**

**Energy Procedia Volume 7**

**Mamallapuram, India  
10 – 13 October 2010**

**Editors:**

**B. Raj**

**ISBN: 978-1-62748-411-4  
ISSN: 1876-6102**

**Printed from e-media with permission by:**

Curran Associates, Inc.  
57 Morehouse Lane  
Red Hook, NY 12571



**Some format issues inherent in the e-media version may also appear in this print version.**

Copyright© (2010) by Elsevier B.V.  
All rights reserved.

Printed by Curran Associates, Inc. (2013)

For permission requests, please contact Elsevier B.V.  
at the address below.

Elsevier B.V.  
Radarweg 29  
Amsterdam 1043 NX  
The Netherlands

Phone: +31 20 485 3911  
Fax: +31 20 485 2457

<http://www.elsevierpublishingsolutions.com/contact.asp>

**Additional copies of this publication are available from:**

Curran Associates, Inc.  
57 Morehouse Lane  
Red Hook, NY 12571 USA  
Phone: 845-758-0400  
Fax: 845-758-2634  
Email: [curran@proceedings.com](mailto:curran@proceedings.com)  
Web: [www.proceedings.com](http://www.proceedings.com)



## Contents

Foreword .....	1
Preface .....	3
<b>Nuclear Energy Development</b>	
Inevitability of Nuclear Power in the Asian Region S.K. Jain .....	5
Industrial Prospects for the Optimized use of U, Pu and Th for Sustainable Nuclear Energy Deployment L. Van Den Durpel, B. Guesdon and M. Lecomte .....	21
Advanced Nuclear Reactor Systems – An Indian Perspective R.K. Sinha .....	34
Nuclear Hybrid Energy Systems: Imperatives, Prospects and Challenges S. Aumeier, R. Cherry, R. Boardman and J. Smith .....	51
Challenges of Atomic Energy Regulation in Indian Context S.S. Bajaj .....	55
Research and Technology Breakthroughs in Nuclear Power for Shaping a Sustainable Low-Carbon Energy Future F. Carre .....	60
Current Status of Fast Reactors and Future Plans in India S.C. Chetal, P. Chellapandi, P. Puthiyavinayagam, S. Raghupathy, V. Balasubramaniyan, P. Selvaraj, P. Mohanakrishnan and B. Raj .....	64
Policy Initiatives by the Government of India to Accelerate the Growth of Installed Nuclear Power Capacity in the Coming Years R.B. Grover .....	74
The Status of Generation IV Sodium-Cooled Fast Reactor Technology Development and its Future Project M. Ichimiya .....	79
<b>Fuel Cycle Strategies</b>	
Current Status and Future Plan of Nuclear Fuel Cycle in Japan, with Focus on Human Resource Development S. Tanaka .....	88
Advanced Fuel Cycle Options R. Malmbeck, C. Nourry, M. Ougier, P. Souček, J.P. Glatz, T. Kato and T. Koyama .....	93
Closed Fuel Cycle System for the FBR Transition from LWR T. Fukasawa, J. Yamashita, K. Hoshino, A. Sasahira, T. Inoue, K. Minato and S. Sato .....	103
Recycle Fuel Fabrication for Closed Fuel Cycle in India H.S. Kamath .....	110
Emerging Nuclear Fuel Fabrication Activities in India R.N. Jayaraj .....	120
Performance Assessment of Fuel and Core Structural Materials Irradiated in FBTR K.V. Kasiviswanathan, V. Karthik, C.N. Venkiteswaran, T. Johny, N.G. Muralidharan and J. Joseph .....	129
A Preliminary Assessment of the Adoption of Innovative Technologies in the Fast Reactor Cycle Technology Development (FaCT) Project in Japan K. Sato, S. Kotake, Y. Fujita, and T. Mizuno .....	140
<b>Front End of Fuel Cycle</b>	
Overview of Indian Uranium Production Scenario in Coming Decades R. Gupta and A.K. Sarangi .....	146
Low Grade Uranium Deposits of India – A Bane or Boon A. Chaki, R.K. Purohit and R. Mamallan .....	153
Bioleaching – An Alternate Uranium Ore Processing Technology for India Abhilash, K.D. Mehta, V. Kumar, B.D. Pandey and P. K. Tamrakar .....	158
Felsic Volcanic Rocks, a Potential Source of Uranium – An Indian Overview P.B. Maithani and S. Srinivasan .....	163
Minor Actinide Bearing Fuels: Fabrication and Irradiation Experience in Europe J. Somers .....	169
Technology Breakthrough by Heavy Water Board in Material Support to Indian Nuclear Power Programme A.L.N. Rao .....	177

## Fuel and Materials Development

Materials and Manufacturing Technologies for Sodium Cooled Fast Reactors and Associated Fuel Cycle: Innovations and Maturity B. Raj .....	186
Materials Development for Indian Nuclear Power Programme: An Industry Perspective M. Narayana Rao .....	199
Some Results of Developments and Investigations of Fuel Pins with Metal Fuel for Heterogeneous Core of Fast Reactors of the BN-type Yu.M. Golovchenko .....	205
Thermochemical Aspects of High Plutonia (44%Pu) MOX Fuel S. Vana Varamban, V. Ganesan and P.R. Vasudeva Rao .....	213
A Remotely Operable Facility for Fabrication of Fuel Pins for Test Irradiation T.V. Prabhu, R. Venkata Krishnan, R. Padmanabhan, B.M. Singh, B. Kothandaraman, A. Senapathy, G. Jogeswara Rao, K. Nagarajan and G. Ravisankar .....	222
Irradiation Behavior of FBTR Mixed Carbide Fuel at Various Burn-ups C.N. Venkiteswaran, N. Raghu, V. Karthik, A. Vijayaraghavan, V. Anandraj, T. Ulaganathan, T. Saravanan, V.V. Jayaraj, S. Kurien, J. Philip, T. Johny, N.G. Muralidharan, J. Joseph and K.V. Kasiviswanathan .....	227
Thermal Analysis of Metallic Fuel for Future FBRs V. Verma and A.K. Ghosh .....	234
Development of Structural and Steam Generator Materials for Sodium Cooled Fast Reactors M.D. Mathew, R. Sandhya and K. Laha .....	250
Austenitic Stainless Steels for Fast Reactors – Irradiation Experiments, Property Evaluation and Microstructural Studies V. Karthik, S. Murugan, P. Parameswaran, C.N. Venkiteswaran, K.A. Gopal, N.G. Muralidharan, S. Saroja and K.V. Kasiviswanathan .....	257
Characterisation of High Temperature Phase Stability and Evaluation of Metallurgical Compatibility with SS 304L, of Indigenously Developed Alternate Shielding Material Ferro-Boron for Fast Reactor Applications S. Raju, A.K. Rai, B. Jeyaganesh, M. Vijayalakshmi, T. Jayakumar and B. Raj .....	264
Experimental Measurements of Neutron Attenuation in the Advanced Shield Material Ferro Boron in KAMINI Reactor R.S. Keshavamurthy, D. Venkata Subramanian, R.R. Prasad, A. Haridas, P. Mohanakrishnan and S.C. Chetal .....	273
Plastic Deformation in ODS Ferritic Alloys: A 3D Dislocation Dynamics Investigation K. Gururaj, C. Robertson .....	279

## Reactor Technologies

Towards a Sustainable Future using Pressure Tube Reactor Technology R.B. Duffey and B. Sur .....	286
The AP1000™ Reactor: Passive Safety and Modular Design B. Sutharshan, M. Mutyala, R.P. Vijuk and A. Mishra .....	293
ADS Fuel Developments in Europe: Results from the EUROTRANS Integrated Project F. Delage, R. Belin, X.-N. Chen, E. D'Agata, F. Klaassen, S. Knol, W. Maschek, J.-P. Ottaviani, A. Rineiski, V. Sobolev, J. Somers, D. Staicu, R. Thetford, J. Wallenius, B. Wernli .....	303
French SFR R&D Program and Design Activities for SFR Prototype ASTRID F. Gauche and J. Rouault .....	314
Challenges in Manufacture of PFBR Steam Generators T.K. Mitra, A. Pai and P. Kumar .....	317
Twenty Five Years of Operating Experience with the Fast Breeder Test Reactor K.V. Suresh Kumar, A. Babu, B. Anandapadmanaban and G. Srinivasan .....	323
Computational Fluid Dynamic Studies on Gas Entrainment in Fast Breeder Reactors K. Satpathy, K. Velusamy and P. Chellapandi .....	333
Self Sloshing of Thermal-Stratification Interface in LMFBR Hot Plenum N. Tanaka .....	340
Remote Leak Sealing of Biological Shield Cooling System of FBTR N. Manimaran, B.S. Panigrahi and G. Srinivasan .....	346
Steam Generators for Future Fast Breeder Reactors R. Nandakumar, S. Athmalingam, V. Balasubramaniyan and S.C. Chetal .....	351
Development of Innovative Reactor Assembly Components towards Commercialization of Future FBRs P. Chellapandi, P. Puthiyavinayagam, V. Balasubramaniyan, S. Raghupathy, V. Rajan Babu, S.C. Chetal and B. Raj .....	359
Analysis of PHWR LP Turbine Steady State Using RELAP/SCDAP Code B.M. Sharma, A. Tiwari, A. Srivastava, R. Kumar, H.G. Lele, A. Khanna and P. Munshi .....	367
En-Masse Coolant Channel Replacement in Indian PHWR J.P. Varghese, V.S. Verma, C.D. Rajput and K. Ramamurthy .....	374
Investigations on Neutronic Decoupling Phenomenon in Large Nuclear Reactors O.P. Singh and Obaidurrahman K. ....	384

## Reprocessing Technologies

Korean Pyrochemical Process R&D Activities H. Lee, J.-M. Hur, J.-G. Kim, D.-H. Ahn, Y.-Z. Cho and S.-W. Paek .....	391
---	-----

Pyrochemical Reprocessing of Spent Fuel by Electrochemical Techniques Using Solid Aluminium Cathodes P. Souček, R. Malmbeck, C. Nourry, and J.-P. Glatz .....	396
State of the Art of Pyroprocessing Technology in Japan T. Inoue, T. Koyama, and Y. Arai .....	405
Fast Reactor Fuel Reprocessing Technology: Successes and Challenges R. Natarajan and B. Raj .....	414
Nuclear Rare Metals and their Separation in Advanced ORIENT Cycle Strategy M. Ozawa, S. Koyama, and T. Suzuki. ....	421
High Performance Separation and Supercritical Extraction of Lanthanides and Actinides A. Datta, K. Sujatha, R. Kumar, N. Sivaraman, T.G. Srinivasan and P.R. Vasudeva Rao .....	425
Development of Pyrochemical Reprocessing for Spent Metal Fuels K. Nagarajan, B. Prabhakara Reddy, S. Ghosh, G. Ravisankar, K.S. Mohandas, U. Kamachi Mudali, K.V.G. Kutty, K.V. Kasi Viswanathan, C. Anand Babu, P. Kalyanasundaram P.R. Vasudeva Rao and B. Raj .....	431
Development of Pyropartitioning Process to Recover Minor Actinide Elements from High Level Liquid Waste K. Uozumi, Y. Sakamura, K. Kinoshita, T. Hijikata, T. Inoue and T. Koyama .....	437
Separation of Thorium and Uranium by Sulfide Method N. Sato and A. Kirishima. ....	444
Extraction Chromatography Experiments on Repeated Operation using Engineering Scale Column System S. Watanabe, I. Goto, K. Nomura, Y. Sano and Y. Koma. ....	449
Extraction of Valuable Elements in Spent Nuclear Fuel by using Pyridine Resin T. Suzuki, M. Ozawa, S. Koyama and M. Osaka .....	454
Process Development for Fabrication of Zircaloy-4 Dissolver Assembly for Reprocessing of Spent Nuclear Fuel S. Tonpe, N. Saibaba, R.N. Jayaraj, A. Ravi Shankar, U. Kamachi Mudali and B. Raj .....	459
Materials Development and Corrosion Issues in the Back End of Fuel Cycle U. Kamachi Mudali, A. Ravishankar, S. Ningshen, G. Suresh, R. Sole and K. Thyagarajan .....	468

## Waste Management

Developments in Back End of the Fuel Cycle of Indian Thermal Reactors S.D. Misra .....	474
Spent Fuel Waste Disposal: Analyses of Model Uncertainty in the MICADO Project B. Grambow, C. Ferry, I. Casas, J. Bruno, J. Quinones and L. Johnson. ....	487
Effect of Boundary Conditions on Thermohydraulic Behaviour of Clay Buffer used in Nuclear Waste Repository A. Arul Peter, G. Mamidi, K. Murugesan, U.K. Sharma, D. Akanshu Sharma and P. Arora .....	495
Treatment of Plastic Waste by Melt Densification—Operational Experience at CWMF S.V.S. Rao, B. Paul, A.G. Shanmugamani, K. Paramasivan and P.K. Sinha .....	502
Development of Mixed Microbial Granular Biofilms for Denitrification of Concentrated Wastes T.V. Krishna Mohan, Y.V. Nancharaiah, V.P. Venugopalan, P.M. Satyasai and S.V. Narasimhan .....	507
Arresting the Accidental Discharge of Nuclear Wastes by Modeling the Fuel and Clad A.K. Saxena. ....	512
Studies on Novel Matrices for High Level Waste from Fast Reactor Fuel Reprocessing K. Joseph, R. Asuvathraman, R. Raja Madhavan, H. Jena, K.V. Govindan Kutty and P.R. Vasudeva Rao .....	518
Melt Crystallization Process Treatment of LiCl Salt Waste Generated from Electrolytic Reduction Process of Spent Oxide Fuel Y.-Z. Cho, B.-G. Ahn, H.-C. Eun, J.-S. Jung and H.-S. Lee .....	525
Immobilization of Lanthanide Oxides Waste from Pyrochemical Process B.G. Ahn, H.S. Park, I.T. Kim, Y.J. Cho and H.S. Lee. ....	529
Studies on Steam Pyrolysis of Amides as a Waste Solvent Management Method D.D. Dicholkar, V.G. Gaikar and S. Kumar .....	534

## Basic Research, Enabling Technologies and Applications of Nuclear Energy

Nuclear Science and Data Needs for Advanced Nuclear Systems R.A. Forrest .....	540
Societal Applications of Nuclear Technology in Health Care, Industry and Water Resource Management in India V. Venugopal .....	553
Laser Applications in Indian Nuclear Power Programme P.D. Gupta .....	560
Applications of Accelerator Technology and its Relevance to Nuclear Technology R.K. Bhandari and M.K. Dey .....	577
Computational Intelligent Systems for Prototype Fast Breeder Reactor M.L. Jayalal, T. Jayanthi, S.A.V. Satya Murty and P.S. Swaminathan .....	589
Application of Accelerators for Nuclear Systems: Accelerator Driven System (ADS) P.K. Nema .....	597
Operating Experience of High Temperature Sodium Loops for Material Testing M. Shanmugavel, S. Vijayaraghavan, P. Rajasundaram, T. Chandran, M. Shanmugasundaram, K.K. Rajan and P. Kalyanasundaram ..	609
Numerical and Experimental Studies on the Performance of Thermal Baffles in Sodium Heated Steam Generator V. Vinod, L.S. Sivakumar, S. Kishore, K. Thanigairaj, V.A. Suresh Kumar, I.B. Noushad, K.K. Rajan and P. Kalyanasundaram ...	616

Design, Development and Testing of a Large Capacity Annular Linear Induction Pump P. Sharma, L.S. Sivakumar, R. Rajendra Prasad, D.K. Saxena, V.A. Suresh Kumar, B.K. Nashine, I.B. Noushad, K.K. Rajan and P. Kalyanasundaram .....	622
Development and Testing of PM Flowmeter with Samarium Cobalt Magnet Assembly G. Vijayakumar, B.K. Nashine, K.K. Rajan and P. Kalyanasundaram .....	630
Development of Helium Leak Testing System and Procedure for Testing Welds of Steam Generator R.M. Shriwardhankar, P.B. Patil and M. Limaye .....	638
Experience with Dilute Chemical Decontamination in Indian Pressurized Heavy Water Reactors S.Velmurugan, A.L. Rufus, V.S. Sathyaseelan, V. Subramanian V.K. Mittal and S.V. Narasimhan .....	645
Validation of CFD and Thermal Hydraulics Codes by Digital Particle Image Velocimetry R.K. Singh and V.M. Joshi .....	650
Simulation and Integrated Testing of Process Models of PFBR Operator Training Simulator T. Jayanthi, H. Seetha, K.R.S. Narayanan, N. Jasmine, R. Nawlakha, B. Sankar, J. Chakraborty, S.A.V. SatyaMurty and P. Swaminathan .....	653
Sodium Aerosol Studies for Fast Reactor Safety Baskaran R., Subramanian V., Venkatraman B. and Chellapandi P. ....	660
Environmental Radiological Monitoring Around Kalpakkam S. Venkataraman, S. Ramkumar, T. Jesan, A.G. Hegde, P.K. Sarkar and K. Ramamurthy .....	666
Knowledge Management in Fast Reactors K.K. Kuriakose, S.A.V. Satya Murty, P. Swaminathan and B. Raj .....	672