



International Conference on the Future of Heavy Water Reactors (HWR-Future) 2011 October 2-5



Atucha I and II Power Plants (www.atucha2.com)



Qinshan Phase-III Power Plant (www.AECL.ca)



Rajasthan Atomic Power Station (www.thehindu.com)

**Ottawa Marriott Hotel
Ottawa, Ontario
Canada**



Our Sincere Appreciation to



AECL Nuclear Laboratories



Candu Energy Inc.



Government of Canada



Co-Sponsoring Agencies and Societies



Sunday 2011 October 02

16:30-18:00 Registration

18:30-20:30 Opening Reception

Room: Summit



Monday 2011 October 03

07:00-08:00 Continental Breakfast (North Ballroom)

08:00-10:15 Opening Plenary

Room: North Ballroom

Chairs:

- **Derek Lister** (University of New Brunswick)
- **Soo-Sung Kim** (Korea Atomic Energy Research Institute)

08:00-08:10 WELCOMING ADDRESS

- **Jonathan Will, Director General, Electricity Resources Branch, Energy Sector, Natural Resources Canada**

08:10-08:35 PLENARY TALK 1

The Future of Heavy Water Reactors – Candu Energy Perspective

- **Jerry Hopwood** (Candu Energy Inc.)

08:35-09:00 PLENARY TALK 2

AECL Nuclear Laboratories –Continuing the Path of Science and Technology Innovations

- **Bill Kupferschmidt** (AECL Nuclear Laboratories)

09:00-09:25 PLENARY TALK 3

IAEA Programme to Support HWR Technology Development

- **Jong Ho Choi** (International Atomic Energy Agency)

09:25-09:50 PLENARY TALK 4

Canadian Gen-IV Heavy Water Reactor Development Program

- **Daniel Brady** (Natural Resources Canada)

09:50-10:15 PLENARY TALK 5

Roadmap for Human Resources for Expanded Indian Nuclear Industry

- **A.R.K. Singh** (Bhabha Atomic Research Centre), **B.G.R. Srinivasan** (NPCIL) and **C.O.P. Goyal** (TAPS)

10:15-10:40 BREAK (NORTH BALLROOM)



Monday 2011 October 03

- 10:40-12:20 Reactor Design**
Room: North Ballroom
Chairs:
- **Jerry Hopwood** (Candu Energy Inc.)
 - **R.K. Singh** (Bhabha Atomic Research Center)
- 10:40-11:05 The EC6--An Enhanced Mid-Sized Reactor with Fuel Cycle Applications**
Michael Soulard, Stephen Yu, Jerry Hopwood and Ian J. Hastings (Candu Energy Inc.)
- 11:05-11:30 Enhanced CANDU6: Reactor Core Design and Fuel Cycle Flexibility**
M. Ovanes, P.S.W. Chan, J. Mao, N. Alderson (Candu Energy Inc.)
- 11:30-11:55 ROP Design for Enhanced CANDU 6 Reactor**
J. Hu, D. Scherbakova, D. Kastanya, M. Ovanes (Candu Energy Inc.)
- 11:55-12:20 I&C Design Changes for the Enhanced CANDU 6 Reactor**
J. de Grosbois, G. Raiskums, M. Soulard (Candu Energy Inc.)
- 12:20-13:30 LUNCH (NORTH BALLROOM)**

Monday 2011 October 03

- 10:40-12:20 HWR Technology**
Room: Wellington
Chairs:
- **Bill Kupferschmidt** (Atomic Energy of Canada Limited)
 - **Jong Ho Choi** (International Atomic Energy Agency)
- 10:40-11:05 The Role of A Technology Demonstration Program for Future Reactors**
A. Viktorov (Canadian Nuclear Safety Commission)
- 11:05-11:30 ACR Technology for CANDU Enhancements**
Stephen Yu, Ranjit Singh and Mike Soulard (Candu Energy Inc.)
- 11:30-11:55 The role of AECL's Pump Seals Program for Heavy Water Reactors**
Dave Rhodes, Tim Sykes and Jintong Li (Atomic Energy of Canada Limited)
- 11:55-12:20 Improved Zr-2.5Nb Pressure Tubing for Future HW Reactors**
G.A. Bickel, L. Walters and M. Griffiths (Atomic Energy of Canada Limited)
- 12:20-13:30 LUNCH(NORTH BALLROOM)**



Monday 2011 October 03

- 13:30-14:50 Physics and Neutronics**
Room: North Ballroom
Chairs:
- **Ken Kozier** (Atomic Energy of Canada Limited)
 - **Yonghee Kim** (Korea Advanced Institute of Science and Technology)
- 13:30-13:55 Status of Deuterium Nuclear Data for the Simulation of Heavy Water Reactors**
K.S. Kozier, D. Roubtsov, R. Rao (Atomic Energy of Canada Limited), J.P. Svenne (University of Manitoba and Winnipeg Institute for Theoretical Physics), L. Canton (Istituto Nazionale di Fisica Nucleare), A.J.M. Plompen (EC-JRC-Institute for Reference Materials and Measurements), M. Stanoiu (Horia Hulubei National Institute for Physics and Nuclear Engineering), N. Nankov and C. Rouki (EC-JRC-Institute for Reference Materials and Measurements)
- 13:55-14:20 Current Developments and Future Challenges in Physics Analyses of The NRU Heavy Water Research Reactor**
S. Nguyen, B. Wilkin and T. Leung (Atomic Energy of Canada Limited)
- 14:20-14:45 Measurement and Simulation of The Gamma Radiation Profile Inside A CANDU Reactor**
C. Jewett, S. Yue, G. Jonkmans, B. Sur (Atomic Energy of Canada Limited), D. Comeau and D. Taylor (Point Lepreau Generating Station)
- 14:45-15:10 Operational Transparency: An Advanced Safeguards Strategy for Future On-Load Refuelled Reactors**
J.J. Whitlock and D. Trask (Atomic Energy of Canada Limited)
- 15:10-15:40 BREAK (NORTH BALLROOM)**

Monday 2011 October 03

- 13:30-14:50 Thermalhydraulics (I)**
Room: Wellington
Chairs:
- **Stephen Yu** (Candu Energy Inc.)
 - **Joo Hwan Park** (Korea Atomic Energy Research Institute)
- 13:30-13:55 Safety Analysis Methodology with Assessment of the Impact of the Prediction Errors of Relevant Parameters**
A. V. Galia (Canadian Nuclear Safety Commission)
- 13:55-14:20 An Overview of Thermal Hydraulic Design Validation Studies for AHWR**
R. K. Bagul, Manish Sharma, D. S. Pilkhwal, P. K. Vijayan and R. K. Sinha (Bhabha Atomic Research Center)
- 14:20-14:45 The BEPU (Best Estimate Plus Uncertainty) Challenge in Current Licensing of Nuclear Reactors**
F. D'Auria, A. Petrucci, N. Muellner (Nuclear Research Group of San Piero s Grado) and O. Mazzantini (NA-SA)
- 14:45-15:10 The Effect of a CANDU Fuel Bundle Geometric Variation on Thermal Hydraulic Performance**
Jun Ho Bae, Joo-Hwan Park (Korea Atomic Energy Research Institute)
- 15:10-15:40 BREAK (NORTH BALLROOM)**



Monday 2011 October 03

- 15:40-17:20 Advanced Fuel Cycle**
Room: North Ballroom
Chairs:
- **Jeremy Whitlock** (Atomic Energy of Canada Limited)
 - **Pritam Das Krishnani** (Bhabha Atomic Research Center)
- 15:40-16:05 Fuel Cycles—A Key to Future CANDU Success**
Sermet Kuran, Jerry Hopwood and Ian J. Hastings (Candu Energy Inc.)
- 16:05-16:30 Advanced Fuel Cycle Development at Chalk River Laboratories**
Mark Floyd (Atomic Energy of Canada Limited)
- 16:30-16:55 A Step Towards Closing The CANDU Fuel Cycle: An Innovative Scheme for Reprocessing Used CANDU Fuel**
F. Collins and D. Lister (University of New Brunswick)
- 16:55-17:20 Use of Recycled Uranium in CANDU Reactors**
Catherine Cottrell (Candu Energy Inc.), Zhenhua Zhang, Mingjun Chen (Third Qinshan Nuclear Power Corporation), Mustapha Boubcher and Sermet Kuran (Candu Energy Inc.)
- 17:20 END OF DAY 1**

Monday 2011 October 03

- 15:40-17:20 Refurbishment**
Room: Wellington
Chairs:
- **Ron Mottram** (Bruce Power)
 - **Sunil K. Sinha** (Bhabha Atomic Research Center)
- 15:40-16:05 Designing and Operating New Nuclear Power Plants for Future Refurbishment - Regulatory Perspective**
A. Omar, H. Khouaja, B. Carroll, K. Kirkhope (Canadian Nuclear Safety Commission)
- 16:05-16:30 Safety Benefits from CANDU Reactor Replacement - A Case Study**
R. Mottram (Bruce Power), J.W.F. Millard (Candu Energy Inc.) and P. Purdy (Bruce Power)
- 16:30-16:55 Steam Generator and Preheater Tube ID Fouling and the Impact on Reactor Inlet Header Temperature and Eddy Current Inspections**
K. Choung, K. Sedman and A. Glover (Bruce Power)
- 16:55-17:20 Development of Advanced Techniques for Life Management and Inspection of Advanced Heavy Water Reactor (AHWR) Coolant Channel Components**
K. Madhusoodanan, S.K. Sinha, Kundan Kumar, T.V. Shyam, Sanjay Panwar, B.S.V.G. Sharma, J.N. Kayal and R.K. Sinha (Bhabha Atomic Research Centre)
- 17:20 END OF DAY 1**



Tuesday 2011 October 04

- 07:30-08:30 Continental Breakfast (North Ballroom)**
- 08:30-10:10 Thorium Fuel**
Room: North Ballroom
Chairs:
- **Sermet Kuran** (Candu Energy Inc.)
 - **Pritam Das Krishnani** (Bhabha Atomic Research Center)
- 8:30-8:55 Benefits of Transitioning to A Thorium Cycle**
G.W.R. Edwards and B. Hyland (Atomic Energy of Canada Limited)
- 8:55-9:20 Fuel Cycle Flexibility in Advanced Heavy Water Reactor (AHWR) with the Use of Th-LEU Fuel**
Amit Thakur, Baltej Singh, Neelima Prasad Pushpam, Vishal Bharti, Umasankari Kannan, P.D. Krishnani and R.K. Sinha (Bhabha Atomic Research Centre)
- 9:20-9:45 Moving Towards Sustainable Thorium Fuel Cycles**
B. Hyland and H. Hamilton (Atomic Energy of Canada Limited)
- 9:45-10:10 Thorium Fuelled CANDU Reactors**
Yang Ruan, Catherine Cottrell, Robert Bodner, Ian Hastings and Sermet Kuran (Candu Energy Inc.)
- 10:10-10:40 BREAK (NORTH BALLROOM)**

Tuesday 2011 October 04

- 07:30-08:30 Continental Breakfast (North Ballroom)**
- 08:30-10:10 Thermalhydraulics (II)**
Room: Wellington
Chairs:
- **Stavros Tavoularis** (University of Ottawa)
 - **Joo Hwan Park** (Korea Atomic Energy Research Institute)
- 8:30-8:55 Modeling of Critical Heat Flux in Light-Water Flow with Heavy-Water-Based Correlation**
L.K.H. Leung (Atomic Energy of Canada Limited)
- 8:55-9:20 Experimental and Computational Thermalhydraulics Research Related to CANDU Reactor Operation and Safety**
S. Tavoularis, D. Chang, E. Rind, G. Choueiri, Y. Liu, H. Shaban and E. Lessard (University of Ottawa)
- 9:20-9:45 Experimental Verification of CFD & Thermal Hydraulics Codes by Quantitative Flow Visualisation**
R.K. Singh, A.K. Kansal, N.K. Maheshwari, P.K. Vijayan and V.M. Joshi (Bhabha Atomic Research Centre)
- 9:45-10:10 Design of An R-134a Loop for Subcritical and Supercritical Forced-Convection Heat Transfer Studies**
M. Balouch, M.I. Yaras (Carleton University)
- 10:10-10:40 BREAK (NORTH BALLROOM)**



Tuesday 2011 October 04

- 10:40-12:20 Transmutation**
Room: North Ballroom
Chairs:
- **Geoff Edwards** (Atomic Energy of Canada Limited)
 - **Yonghee Kim** (Korea Advanced Institute of Science and Technology)
- 10:40-11:05 Reducing the Impact of Used Fuel by Transmuting Actinides in A CANDU Reactor**
B. Hyland and G.W.R. Edwards (Atomic Energy of Canada Limited)
- 11:05-11:30 Super-Deep-Burn with the FCM (Fully Ceramic Microencapsulated) TRU Fuel in CANDU**
Yonghee Kim, Donny Hartanto (Korea Advanced Institute of Science and Technology) and Fransesco Venneri (Logos Nuclear Systems)
- 11:30-11:55 Transuranic Mixed Oxide Fuel Use in CANDU**
A. C. Morreale, D. R. Novog, and J. C. Luxat (McMaster University)
- 11:55-12:20 Quasi-Heterogeneous Discrete Ordinates CANDU Calculations Using ATTILA**
T. Preeti and R.P. Rulko (Canadian Nuclear Safety Commission)
- 12:20-13:30 LUNCH (NORTH BALLROOM)**

Tuesday 2011 October 04

- 10:40-12:20 Supercritical Water-Cooled Reactor**
Room: Wellington
Chairs:
- **Daniel Brady** (Natural Resources Canada)
 - **Jianqiang Shan** (Xi'an Jiaotong University)
- 10:40-11:05 A Next Generation Heavy Water Nuclear Reactor with Supercritical Water as Coolant**
L.K.H. Leung, M. Yetisir, W. Diamond, D. Martin, J. Pencer, B. Hyland, H. Hamilton, D. Guzonas and R. Duffey (Atomic Energy of Canada Limited)
- 11:05-11:30 Physics Aspects of the Pressure Tube Type SCWR Preconceptual Design**
J. Pencer and B. Hyland (Atomic Energy of Canada Limited)
- 11:30-11:55 Optimization of Thorium-Uranium Content in A 54-Element Fuel Bundle for Use in A CANDU-SCWR**
D. W. Hummel and D. R. Novog (McMaster University)
- 11:55-12:20 Review of Research on CANDU-SCWR in XJTU**
Jianqiang Shan, Liangzhi Cao, Qincheng Bi And Junli Gou (Xi'an Jiaotong University)
- 12:20-13:30 LUNCH (NORTH BALLROOM)**



Tuesday 2011 October 04

13:30-14:50 **Panel Discussion on "Current Developments and Challenges In Heavy Water Reactor Physics Analyses"**

Room: North Ballroom

Chair:

- **Parvaiz Akhtar** (Canadian Nuclear Society)
- **Dumitru Serghiuta** (Canadian Nuclear Safety Commission)

Panelists:

A. Buijs (MacMaster University, Canada)
J.V. Donnelly (AMEC-NSS, Canada)
Y. Kim (Korea Atomic Institute of Science and Technology)
P.D. Krishnani (Homi Bhabha National Institute, India)
D.D. Radford (Atomic Energy of Canada Limited, Canada)
F. Rahnema (Georgia Tech., USA)
P.J. Turinsky (NCSU, USA)

Topics:

- Present neutronics computational schemes for heavy water reactors and challenges related to optimization of operational and licensing needs for life extension
- Full core transport methods in HWR : drivers and trends
- Coupled neutronics-thermalhydraulics codes
- Developmental needs pertaining to advanced HWR designs and new fuel cycles
- Verification and validation activities and related qualification of uncertainties
- Developmental needs to address evolution of regulatory and licensing requirements

15:10-15:40 **BREAK (NORTH BALLROOM)**

Tuesday 2011 October 04

13:30-14:50 **Panel Discussion on "Fuel CHF Enhancement – Technologies to improve safety margin, enhance power output, and mitigate ageing effect"**

Room: Wellington

Moderator:

- **Laurence Leung** (Atomic Energy of Canada Limited)
-

Panelists:

Michel Couture (Canada Nuclear Safety Commission)
De Groeneveld (Atomic Energy of Canada Limited)
Marc Kwee (Bruce Power)
Joo Hwan Park (Korea Atomic Energy Research Institute)
Todd Daniels (Ontario Power Generation)
Ab Tahir (AMEC-NSS)

Topics:

- Past experience
- Current developments
- Analytical support
- Experimental support
- Future trends
- Regulatory and licensing requirements

15:10-15:40 **BREAK (NORTH BALLROOM)**



Tuesday 2011 October 04

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- Full core transport methods in HWR : drivers and trends
- Coupled neutronics-thermalhydraulics codes
- Developmental needs pertaining to advanced HWR designs and new fuel cycles
- Verification and validation activities and related qualification of uncertainties
- Developmental needs to address evolution of regulatory and licensing requirements

17:20 **END OF DAY 2**

18:00-18:30 **PRE-BANQUET GATHERING FOR GROUP PHOTO**

18:30-21:00 **CONFERENCE BANQUET**

Room: North Ballroom

Future of the Heavy Water Reactors and the CNS – the CNS President's Perspective

- **Speaker: Frank Doyle** (Canadian Nuclear Society)

Tuesday 2011 October 04

15:40-17:20 **Panel Discussion on "Fuel CHF Enhancement – Technologies to improve safety margin, enhance power output, and mitigate ageing effect"**

Room: Wellington

Moderator:

- **Laurence Leung** (Atomic Energy Canada Limited)
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Panelists:

Michel Couture (Canada Nuclear Safety Commission)
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Marc Kwee (Bruce Power)
Joo Hwan Park (Korea Atomic Energy Research Institute)
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Ab Tahir (AMEC-NSS)

Topics:

- Past experience
- Current developments
- Analytical support
- Experimental support
- Future trends
- Regulatory and licensing requirements

17:20

END OF DAY 2

18:00-18:30

PRE-BANQUET GATHERING FOR GROUP PHOTO

18:30-21:00

CONFERENCE BANQUET

Room: North Ballroom

Future of the Heavy Water Reactors and the CNS – the CNS President's Perspective

- **Speaker: Frank Doyle** (Canadian Nuclear Society)



Wednesday 2011 October 05

- 07:30-08:30 Continental Breakfast (North Ballroom)**
- 08:30-10:10 Tritium and Moderator-Related Studies**
Room: North Ballroom
Chairs:
- **John G. Roberts** (JGR Chem Inc.)
 - **Ian Castillo** (Atomic Energy of Canada Limited)
- 8:30-8:55 Tritium Emission Reduction Initiatives at CANDU Reactors**
L. Rodrigo (Atomic Energy of Canada Limited), D. Williams and F. Fusca (Ontario Power Generation)
- 8:55-9:20 Removal of Tritiated Light Water from Spent Fuel Bay Using Thermal Stratification**
I. Castillo, H. Boniface, K. Kutchcoskie, D. Barry (Atomic Energy of Canada Limited) and D. Baker (Hatch Engineering Limited)
- 9:20-9:45 Heavy Water Reactor Moderator: Are Changes to Design Requirements Necessary?**
John G. Roberts (JGRchem.inc)
- 9:45-10:10 A Moderator Ion Exchange Model to Predict Carbon-14 Behaviour During Operations**
D.K. Ryland, L. Rodrigo and D.H. Barber (Atomic Energy of Canada Limited)
- 10:10-10:40 BREAK (NORTH BALLROOM)**

Wednesday 2011 October 05

- 07:30-08:30 Continental Breakfast (North Ballroom)**
- 08:30-10:10 Safety Analyses**
Room: Wellington
Chairs:
- **David R. Novog** (McMaster University)
 - **Avinash Jagannath Gaikwad** (Bhabha Atomic Research Center)
- 8:30-8:55 A Composite Analytical Solution for Large Break LOCA**
P. Purdy (Bruce Power), R. Girard (Hydro-Québec), J. Marczak (Ontario Power Generation), D. Taylor (New Brunswick Power), R. Zemdegs (Candu Energy Inc.), T. Kapaklilii (CANDU Owner's Group), G. Balog (AMEC NSS), M. Kozluk (Independent Consultant), A. Oliva (Candesco)
- 8:55-9:20 MARS-KS Assessment on B9802 SBLOCA test in RD-14M Test Facility**
Joosung KIM, Kap KIM and Kwangwon SEUL (Korea Institute of Nuclear Safety)
- 9:20-9:45 PSA-Oriented Analysis of Transients in ATUCHA Unit II PHWR with A RELAP Model**
J. González^{1,4,5}, P. Zanocco^{1,5}, M. Giménez^{1,5}, M. Schivo², O. Mazzantini², M. Caputto^{1,5}, G. Bedrossian³, P. Serrano² and A. Vertullo¹
¹ Comisión Nacional de Energía Atómica (Centro Atómico Bariloche),
² Nucleoeléctrica Argentina S.A., ³ Comisión Nacional de Energía Atómica (Central Nuclear Atucha II), ⁴ Consejo Nacional de Investigaciones Científicas y Tecnológicas, ⁵ Instituto Balseiro
- 9:45-10:10 Safety Assessment of Passive features of Advanced Heavy Water Reactor**
H. G. Lele, A. D. Contractor, Mithilesh Kumar, A. Srivastava, P. Majumdar, D. Mukhopadhyay, Rajesh kumar, A.J. Gaikwad, B. Chatterjee, K.K. Vaze and R.K. Sinha (Bhabha Atomic Research Centre)
- 10:10-10:40 BREAK (NORTH BALLROOM)**



Wednesday 2011 October 05

- 10:40-12:20 Heavy Water Technology**
Room: North Ballroom
Chairs:
- **Don Ryland** (Atomic Energy of Canada Limited)
 - **Peter Ozemoyah** (Tyne Engineering Inc.)
- 10:40-11:05 A New Approach to Heavy Water Upgrading Technology**
P. Ozemoyah, J. Robinson, T. Manifar, V. Robinson (Tyne Engineering Inc), S. Suppiah, H. Boniface (Atomic Energy of Canada Limited)
- 11:05-11:30 Combined Electrolysis and Catalytic Exchange (CECE) Upgraders - An Alternative to Water Distillation (DW) Heavy Water Upgraders**
D. Ryland, H. Boniface, I. Castillo, and S. Suppiah (Atomic Energy of Canada Limited)
- 11:30-11:55 Future Trends for Electrolysers in Nuclear Industry**
T. Manifar, J. Robinson, P. Ozemoyah, V. Robinson (Tyne Engineering Inc.), S. Suppiah, H. Boniface (Atomic Energy of Canada Limited)
- 11:55-12:20 AECL Passive Autocatalytic Recombiners**
L.B. Gardner and K. Marcinkowska (Atomic Energy of Canada Limited)
- 12:20 END OF INT. CONF. HWR-FUTURE**

Wednesday 2011 October 05

- 10:40-12:20 Fuel and Fuel Safety**
Room: Wellington
Chairs:
- **Mark Floyd** (Atomic Energy of Canada Limited)
 - **Khaled Shaheen** (AMEC-NSS)
- 10:40-11:05 Design and Fabrication of Remote Welding System for the Fuel Bundle Assembly**
Soo-Sung Kim, Jung-Won Lee and Geun-II Park (Korea Atomic Energy Research Institute)
- 11:05-11:30 Modelling CANDU Fuel Element and Bundle Behaviour for Performance of Intact and Defective Fuel**
K. Shaheen, J.S. Bell, A. Prudil, and B.J. Lewis (Royal Military College of Canada)
- 11:30-11:55 Evaluation of Fission Product Release Following Single Channel Accidents for Refurbished Wolsong-1**
J.Y. Jung (Korea Atomic Energy Research Institute), E.K. Lee (KHNP-CRI), C.J. Bae (KEPCO E&C) and J.H. Park (Korea Atomic Energy Research Institute)
- 11:55-12:20 Potential Use of High Thermal-Conductivity Fuels in Advanced Heavy-Water Moderated Reactors**
W. Peiman, I. Pioro, and K. Gabriel (University of Ontario Institute of Technology)
- 12:20 END OF INT. CONF. HWR-FUTURE**



Thursday 2011 October 06

Int. Conf. HWR-Future Technical Tour (Registered Participants Only)

07:30 Departure from Ottawa Marriott Hotel (Shuttle bus)

07:30-09:30 Travel from Ottawa to Chalk River Laboratories

09:30-10:30 Welcoming address and Introduction

10:30-12:30 Tour of Chalk River Laboratories Facilities

12:30-13:30 Lunch

13:30-16:00 Tour of Chalk River Laboratories Facilities

16:00-18:00 Travel from Chalk River Laboratories to Ottawa Marriott Hotel (Shuttle bus)





International Conference on Future of Heavy Water Reactors (HWR – Future)

Embedded Panel Discussion:

Current Developments and Challenges in Heavy Water Reactor Physics Analyses

Organized by Reactor Physics Group of Canadian Nuclear Society

**October 4, 2011
Ottawa**



Ottawa Marriott Hotel



Organizing Committee

Dr. Parvaiz Akhtar

Rephys Design and Safety Assessment

Dr. Dumitru Serghiuta

Canadian Nuclear Safety Commission

Dr. Adriaan Buijs

McMaster University

Program

October 4:

13:30 – 17:30

Panellists Presentations and Discussions

Topics

- Present neutronics computational schemes for heavy water reactors and challenges related to optimization of operational and licensing needs for life extension
- Full core transport methods in HWR: drivers and trends
- Coupled neutronics-thermalhydraulics codes
- Developmental needs pertaining to advanced HWR designs and new fuel cycles
- Verification and validation activities and related qualification of uncertainties
- Developmental needs to address evolution of regulatory and licensing requirements

Panellists



Dr. Darren D. Radford
*Manager, Nuclear Science Division
Chalk River Laboratories, AECL, Canada*



Prof. Paul J. Turinsky
North Carolina State University, USA



Dr. P.D. Krishnani
*Head, Reactor Physics Design Division of BARC,
Senior Professor of Homi Bhabha National Institute, India*



Prof. Farzad Rahnema
*Georgia Institute of Technology, George W. Woodruff
School, USA*



Dr. Adriaan Buijs
MacMaster University, Canada



Dr. Yonghee Kim
Associate Professor, KAIST, Korea



Dr. Jim Donnelly
*Principal Consultant in Reactor Physics, AMEC NSS,
Canada*

Co-Chairs



Dr. Parvaiz Akhtar

Dr. Parvaiz Akhtar has a B.Sc. (Hon) in physics and math and a M.Sc. and Ph.D. in Nuclear Engineering from the University of Michigan, Ann Arbor. He has over 35 years of experience in various areas of CANDU design and safety analysis and related regulatory activities.

His first 16 years were spent at the AECL where he worked as a reactor physicist, Head of the Lattice Physics Section and Head of Commissioning Physics and Fuel Warranties Section. His main activities included various aspects of reactor physics and fuel management analyses; certain aspects of nuclear design for Bruce A&B, Pickering B, CANDU 6 and 900MW and 1200MW conceptual studies; commissioning and start-up of CANDU reactors in Canada, S. Korea and Argentina, and, meeting AECL contractual obligations on specific fuel warranties.

In addition to industry experience, Dr. Akhtar has over 20 years of regulatory experience at the AECB/CNSC. He joined as a reactor physicist, established the Reactor Physics and Fuel Section and served first as Section Head and then as Director of the Physics and fuel Division. During this period, his main activities and responsibilities included all aspects of related compliance and licensing issues; raising several generic safety issues to deal with identified deficiencies, resulting LVRF program at Bruce, and related licensing reviews of ACR and MAPLE.

He is currently working as consultant. Recently he was involved in developing CNSC regulatory requirements and review plans for the new builds.

He also recently helped establish Canadian Nuclear Society Reactor Physics Group and is its current chair



Dr. Dumitru Serghiuta

Dr. Dumitru Serghiuta has over 30 years of experience in various areas of CANDU core nuclear design and safety analysis and related regulatory activities.

He has a M.Sc. and Ph.D. in Nuclear Engineering from the University of Bucharest, Romania.

He started his career in 1979 as a researcher at the Institute for Nuclear Research, Pitesti, Romania, where he contributed and led the development of reactor physics methods and computer codes for design, core tracking, and transient and accident analysis of CANDU reactors with natural uranium and advanced fuel cycles, and design of test conditions for CANDU fuel irradiation in the INR TRIGA reactor. His activities included various aspects of reactor physics and development of specific analysis methods (coupled lattice-cell – full core simulation) for core design and fuel management analyses for CANDU reactors with slightly enriched uranium/low void reactivity fuel and thorium fuel.

He joined CNSC (former AECB) in 1996, where he deals with safety assessment and licensing review of power and research reactors and development of independent assessment capabilities and processes in the area of reactor core nuclear design, fuel management and transient and accident analyses for reactors in operation and new reactor designs. He initiated and led generic actions items related to replacement of CANDU reactor physics codes and improvement of core tracking and monitoring software, and has been the technical lead reviewer of core design and nuclear performance for Bruce Low Void Reactivity Fuel project and pre-project reviews of ACR-700, ACR-1000 and EC-6.

Elected member of Executive Committee of Reactor Physics Division of American Nuclear Society (2010 – 2012)

Computational Reactor Physics at Chalk River Laboratories – Future Directions



D.D. Radford

Abstract: For over sixty years, Canada has been a world leader in nuclear research, medicine and energy production. AECL's Chalk River Laboratories (CRL), located in the Upper Ottawa valley at Chalk River ON., has been a significant contributor to Canada's nuclear success, and is the birthplace of the CANDU technology. The global fleet of CANDU and CANDU-derived reactors currently includes approximately 50 reactors. CRL is the "knowledge base" of the Canadian industry, and represents a major producer of medical isotopes and a leader in nuclear environmental stewardship. Currently, AECL is undergoing a major restructuring including the divestiture of its commercial business. As part of the restructuring, AECL is re-focusing its efforts to better align with current Government priorities. The role of the laboratories going forward is viewed by Government to be a national Nuclear Laboratory (NL) applying science and technology for the benefit of Canadians and the world by way of specialized expertise, facilities and the unique ability to work with radioactive materials. As such, the NL seeks to renew its relationships with the Canadian nuclear industry, universities and the regulator, thereby positioning itself as a bridge between these communities.

Ongoing research in the area of reactor physics continues to represent a key activity at the NL in both experimental and software development in support of the design and safe operation of CANDU power reactors.

This presentation will discuss research and outreach efforts currently underway at the NL in computational reactor physics. Areas of current interest include new computational schemes for neutron transport, coupled code development, and advanced HWR and fuel cycle

designs/optimizations. The presentation will discuss specific initiatives including:

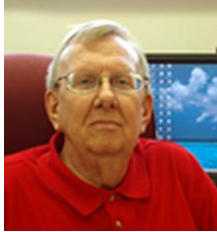
- a) Renewed outreach and collaboration efforts.
- b) Physics modeling of advanced Thorium-based fuel cycles and the SCWR.
- c) The development of reactor physics models for an independent rigorous nuclear safety analysis capability for independent reviews which satisfy the following attributes:
 - Ease-of-use: single input/execution/output
 - General applicability: accurate and useful for many systems
 - Rigorous QA: extensive validation
 - Independent capability: verification of "Industry" software
- d) The application of mesh-free representations of the spatial distribution of the neutron flux to the neutron transport problem.
- e) The development of a 'backbone' providing a common information interface for coupled code calculations.

Bio-sketch: Dr. Radford continues a successful career with AECL, with more than 22 years of research experience holding positions as a senior scientist, program manager, technical lead, and various management roles. Darren is currently the Manager of the Computational Reactor Physics Branch at Atomic Energy of Canada Limited (AECL), and the Program Manger for all activities related to CANDU Inc. Support. He has extensive experience in fundamental research in the development of CANDU reactor technology, including fuel channel design and safety, reactor safety and licensing, and reactor physics. Dr. Radford started his career with AECL at the Whiteshell Laboratories in 1988, and from 2000 to 2002, was on sabbatical from AECL performing materials science research at the Cavendish Laboratory, Cambridge University. In 2002 Dr. Radford was appointed as a Research Professor at the Mechanical Engineering Department, Cambridge University, and rejoined AECL at Chalk River Laboratories (CRL) in 2005.

Dr. Radford is a graduate of the University of Winnipeg, Applied Mathematics and Physics (B.Sc.); University of Manitoba, Mechanical Engineering (M.Sc.); and Carleton University, Mechanical and Aerospace Engineering (Ph.D.).

Dr. Radford is a Member of the American Physical Society; DYMAT (Mechanical and Physical Behaviour of Materials Under Dynamic Loading); the Canadian Nuclear Society; United Kingdom Impact Club; and fellow of the Cambridge Philosophical Society.

The Drivers for Advanced Reactor Physics Capabilities



Prof. Paul J. Turinsky

Abstract: If we consider the prediction capabilities of the various phenomena that are relevant to nuclear power reactors, one would conclude that computational reactor physics displays the best prediction accuracy. So is the continuing effort to further enhance capabilities in this area well founded? The talk will address how the interactions with other phenomena is dependent upon enhanced computational reactor physics capabilities, and the impact of advances in uncertainty quantification and data assimilation on the capabilities required.

Bio-Sketch: Paul J. Turinsky is Professor of Nuclear Engineering at North Carolina State University, where he also services as Coordinator of the Interdisciplinary Graduate Program on Computational Engineering and Sciences, and University Representative to the Battelle Energy Alliance Nuclear University Collaborators which is associated with the operation of Idaho National Laboratory. He also serves as Chief Scientist for the Consortium for Advanced Simulation of Light Water Reactors (CASL), one of the three US Department of Energy's Energy Innovation Hubs.

His area of expertise is computational reactor physics, with a focus on nuclear fuel management optimization, space-time kinetics, sensitivity/uncertainty analysis and adaptive core simulation.

Professor Turinsky is a Fellow of the American Nuclear Society (ANS) and recipient of numerous awards including the Glenn Murphy Award (ASEE), E. O. Lawrence Award in Nuclear Energy (US DOE), Eugene P. Wigner Reactor Physics Award (ANS) and Arthur Holly Compton Award (ANS).

He serves on several advisory committees and retains a consulting practice supporting industry and government.

Development of Full Core Transport Methods in India



Dr. P.D. Krishnani

Abstract: Conventionally, the reactor core design and analysis simulations are performed in two steps: homogenisation of fuel assemblies as infinite lattices, with 1D/2D neutron transport (S_n , collision probability) and use these homogenised parameters in whole core 3-D neutron transport / diffusion simulations. Though the procedure was found to be acceptable with the limited computing power available, concerns over the accuracy of the homogenisation remained. The approximation in homogenising a single lattice at a time, inaccurate boundary conditions on the Wigner cell, averaged cross sections and use of diffusion theory introduce uncertainties requiring large scale validation with experiments. The pin power reconstruction de-homogenisation involves further approximation. With the new generation of reactor designs with more complex geometries, more heterogeneities and newer materials, these approximations would lead to even larger uncertainties. With enormous computing power available today, there is a recent trend to explore the whole core simulations without any spatial homogenisation. Such simulations require the best of modelling, solution algorithms and massive parallelization techniques. Even with the computing resources that are employed, it is a huge task to analyze a benchmark such as proposed in OECD/NEA C5-G7 benchmark problems for LWR configurations with MOX fuel assemblies. Department of Atomic Energy has been currently working on many innovative reactor concepts suited for its needs such as Advanced Heavy Water Reactor (AHWR), Compact high Temperature Reactor (CHTR) etc. For such complex physics design problems, we have initiated a program to develop a comprehensive neutron transport analysis capability. A 3-D whole core neutron transport code, ATES3, based on S_n -method and coarse mesh finite differencing has recently been developed in RPDD, BARC. ATES3 is currently being used in neutron transport simulations of India's heavy water reactor designs such as Advanced Heavy Water Reactor (AHWR) and AHWR-Critical Facility, PHWR etc. The cell/assembly homogenisation is performed with a collision probability/Interface current method based 2-D lattice

analysis code ITRAN and used in ATES3. It has been envisaged to use ATES3 to simulate heavy water reactor cores without spatial homogenisation. For such efforts, efficient acceleration technique, like Krylov subspace based solution schemes, have been developed and the code has also been parallelised on BARC's ANUPAM series of supercomputers. In addition, RPDD has also initiated work on the development of Method of Characteristics based code and has developed a 1-D MoC code 'Inmocs' which is being expanded to 2-D MoC code.

Bio-Sketch: Dr. Krishnani has been working in area of reactor physics in Bhabha Atomic Research Centre since 1974. He currently heads Reactor Physics Design Division of BARC and is also a Senior Professor of Homi Bhabha National Institute. He was awarded Ph.D. degree in Physics from Mumbai University for the thesis entitled "A Method for Solving Integral Transport Equation for Pressurized Heavy Water Cluster Geometry" in 1985. He has developed a number of lattice analysis codes for PHWRs, PWRs, BWRs and HTRs which are most sophisticated and state-of-the-art software for reactor design. Presently, he is also associated with the development of neutron transport theory code based on method of characteristics and development of fuel management code for PHWRs based on automatic selection of fuel channels for refueling and core follow up. He has also taken part in various CRPs on PHWRs, BWRs, PWRs and VVERs initiated by IAEA. He was acting as Technical Officer from India for the INPRO Collaborative Project on "Further Investigations of the U233/Th Fuel Cycle" and was the Chief Scientific Investigator for the CRP on "Development of Small Reactor without On-Site Refuelling". He has contributed towards the study of utilization of thorium and MOX fuel in TAPS-1/2 as well as 220 MWe PHWR. Dr. Krishnani has been associated with the design of 540 MWe PHWR, Advanced Heavy Water Reactor (AHWR) and high temperature reactors. He is in charge of the physics design of AHWR, Compact High Temperature Reactor and Innovative High Temperature Reactor for Hydrogen production. He is member of number of safety committees in AERB and BARC. He has more than 300 publications to his credit in the international journals, National and International symposia and in the form of reports.

Current Challenges and Developments in Whole Core Radiation Transport Methods for Heavy Water Reactor Physics Analyses



Prof. Farzad Rahnema

Abstract: We will first discuss the limitations of the current methods used in heavy water reactor (HWR) physics analysis and then highlight the challenges of ongoing developments in whole core transport methods will be highlighted. We conclude by introducing an innovative radiation transport method for whole core water reactor calculations including the HWRs.

The new method overcomes many of the limitations inherent in current industry methods which are based on loosely coupled transport and diffusion theories. Notable limitations are the use of single lattice transport theory calculations with approximate boundary conditions (e.g., full specular reflection) and geometry, cross section homogenization, ad hoc de-homogenization (fuel pin reconstruction) and homogenized diffusion theory calculations.

Bio-Sketch: Dr. Rahnema received his PhD from the University of California in Los Angeles in 1981. From 1981 to 1992, he was at General Electric Nuclear Energy. His responsibility included GE's 3-D Nuclear/Thermal Hydraulics BWR Core Simulator PANACEA used for design, monitoring and prediction of BWR cores. He led the development of three versions (8-10) of the simulator. He joined Georgia Institute of Technology in October 1992 and is currently Professor and

Chair of the Nuclear and Radiological Engineering and Medical Physics Programs. He also holds an adjunct Professor appointment at the Emory University Radiation Oncology Department. His research activity and interest have been in the areas of reactor physics and radiation transport.

Dr. Rahnama is a Fellow of the American Nuclear Society (ANS), chair of the honors and award committee of the ANS mathematics and computation (M&C) division. He has also chaired the ANS reactor physics and M&C divisions as well as the Board of Directors of the Southeast Universities Nuclear Reactors Institute for Science and Education (SUNRISE)

On the Validation and Qualification of Reactor Physics Codes



Dr. Adriaan Buijs

Abstract: In my presentation, I will briefly outline some of the steps that need to be taken to gain confidence in the validity of calculations of the neutronic properties of reactor cores. These include benchmarking through code-to-code comparisons, validation of codes through comparisons with experiments, sensitivity and uncertainty calculations, and the design of appropriate experiments for code validation.

Bio-Sketch: Dr. Adriaan Buijs has been with Atomic Energy of Canada Limited from 2001 to 2008, first as senior scientist in safety and licensing in the Reactor Core Physics division, then as section head for neutronic overpower protection in CANDU reactors.

In 2006 he became manager of the Physics Design group for the ACR-1000. In January 2009 Adriaan was appointed as professor in the Engineering Physics Department of McMaster University in Hamilton.

Adriaan has a Master's degree in experimental physics from the State University in Utrecht. He received a PhD from the same

University on work on photon-photon collisions studied at the Stanford Linear Accelerator Center in California, USA. Prior to joining AECL, he was fellow and staff member at CERN, the European Centre for Particle Physics from 1986 to 1994. From 1994 to 2001 he was full professor of experimental physics at Utrecht University and director of the particle physics department.

Adriaan has been chairman of the Sheridan Park Branch of CNS from 2004 to 2008, secretary of the CNS executive from 2004 to 2006, and president in 2010/11. He is currently treasurer of the Golden Horseshoe Branch of the CNS.

Needs for Improvements in the CANDU Reactor Physics Methodologies



Dr. Yonghee Kim

Abstract: Starting with a brief review of the current physics methods, the presentation tackles current technical issues and problems in the area of the physics analysis of CANDU, including:

- Challenges and issues in the lattice calculations including fuel depletion
 - Higher-fidelity methods to account for the Doppler broadening effects
 - Need to develop few-group equivalent parameters in systematic way
- Challenges and issues in the 3-D core analyses
 - Need to develop high-order nodal methods based on the equivalence theory
 - Need for a better TH-coupled core analysis
 - Needs for the microscopic depletion methods
- Issues related to the safety parameters of CANDU 6

- Potential physics challenges in advanced application of CANDU

Bio-Sketch: Dr. Yonghee Kim is currently associate professor at Korea Advanced Institute of Science and Technology (KAIST). He has a B.Sc in Nuclear Engineering from Seoul National University and received his M.Sc and Ph.D in Nuclear Engineering from KAIST in 1990 and 1995, respectively. He was a Senior Researcher at KEPRI, Principal Researcher at KAERI, visiting scientist at Argonne National Laboratory and associate professor at Ulsan National Institute of Science and Technology, before joining KAIST. He has extensive research and management experience holding positions as consultant for General Atomics and Thor Technology Norway (Thorium-Plutonium fuel development), program manager for bilateral nuclear collaboration between Korea and South Africa, and director of BAERI (Basic Atomic Energy Research Institute) for "Key Technology Development for High-performance. Ultra-long-life Core Fast Reactor" program. He is a member of KNS and ANS, and member of review committee of "Nuclear Engineering and Technology" (the Journal of KNS).



Dr. Jim Donnelly

Bio-Sketch: Dr. Jim Donnelly is the Principal Consultant in Reactor Physics at AMEC NSS. In this role, responsibilities include leadership and oversight in a wide range of reactor-physics applications primarily in support of operating CANDU reactors. Background includes lattice- and core-code development, design and safety analysis of CANDU, research, and small reactors. Graduated from the University of Waterloo in Applied Physics, and received a Masters in Nuclear Engineering from the University of Toronto.



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