McMaster University – John Luxat IRC
– Dave Novog

NSERC/UNENE Industrial Research Chair in Nuclear Safety Analysis

Overview

The research focus of the NSERC/UNENE Industrial Research Chair and Associate Chair in Nuclear Safety Analysis at McMaster University is nuclear safety analysis methods and nuclear safety thermalhydraulics. The scope of the research covers many disciplines reflecting the multi-disciplinary nature of nuclear safety analysis. This requires academic knowledge and skills that can be found in the Faculty of Engineering at McMaster University. The Chair program enhances and extends this knowledge and skills base while providing an active link that supports the Canadian nuclear industry. The Chair program has enabled McMaster University to establish a robust, innovative and sustainable faculty research network during its first 5 year term, and with the approval of the second five year term the Chair and Associate Chair will make significant long term contributions to the Canadian nuclear industry and the international nuclear energy community.

The resulting knowledge, skills and innovation are applied to nuclear safety issues of critical importance to industry in improving safe operation and competitiveness of nuclear power generation. Novel research is aimed at improving the quantification of safety margins, helping to regain operating margins of nuclear generating units, improving the quality, efficiency and cost effectiveness of nuclear safety analysis and supporting the development of advanced CANDU reactor designs. This research continues to provide measurable contributions to operating power plants by improving the safety, reliability and competitiveness of generating units as an environmentally beneficial contributor to Canada's energy supply and enhancing the competitiveness of Canadian nuclear technology in global markets.

Development of the Research Chair

The NSERC-UNENE Industrial Research Chair in Nuclear Safety Analysis was established in 2004 with John C. Luxat as the Executive IRC. Subsequently David R. Novog was hired as the Associate IRC Chair in 2006. Both chairs had a rapid growth of graduate students in Term 1 of the program and now have some of the largest research groups within the Faculty of Engineering. In addition both Dr. Luxat and Novog supervise and co-supervise additional students in the other Departments and Faculties at McMaster. In 2009 Dr. Luxat's Executive IRC was converted to a Senior IRC and both he and Dr. Novog had their terms renewed for a further 5 year term following an NSERC site visit.

In 2008, McMaster University, along with five partner universities, was awarded an Ontario Research Fund – Research Excellence (ORF-RE) award entitled "Nuclear Ontario" with Dr. Luxat as the Principal Investigator. This new network establishes a research program aimed at developing concepts, materials and designs for existing and next generation power plants as well as examining options for the back end of the fuel cycle. This complementary program to UNENE provides an addition $5M of provincial funding to support nuclear research at six universities in Ontario. In 2009, Dr. K. Krishnan was contracted as Managing Director for Nuclear Ontario and research continues to accelerate under this program. In 2009, Dr. Luxat led a regional, multi-university, proposal to the Canadian Foundation for Innovation (CFI) and the Ontario Ministry for Research and Innovation (MRI) to establish the Center for Advanced Nuclear Systems (CANS). This $23M regional facility will provide a suite of irradiated material handling and testing equipment and a thermal testing laboratory(at McMaster), and a dose laboratory (at UOIT). This infrastructure, coupled to the McMaster Nuclear Reactor and the Canadian Center for Electron Microscopy, provides a world class materials and thermal testing center unique in North America. The project was supported by a majority of Canadian nuclear energy related companies (OPG, Bruce Power, AECL, Kinetrics) as well as a number of leading international organizations (EPRI, EdF, TEPCO, Bechtel). In 2008, Dr. Novog received a $275k CFI - Leaders Opportunity Fund grant for a Phase Doppler Anemometer System for thermalhydraulic experiments. Finally, in 2008 and 2009 the AIRC received additional funding from AECL for a CRD in SCWR analysis methods and from NRCan for a CRD in thermalhydraulic simulations of SCWRs totaling approximately $300k.

<u>Research Facilities</u>

Computational Facilities

A Linux-based Beowulf high performance computer cluster was acquired for the research group and is located in the Nuclear Safety Research Building. The cluster consists of a total of six nodes each with four high performance AMD 64-bit Opteron processors, providing a total of 24 processors. Each node contains, associated memory and local hard drives and the server node contains an additional RAID disc storage system. In addition, two new analysis stations (purchased with NRCan funding) add an addition 16 processors dedicated to CFD and safety analysis computing.

In addition to the hardware, FLUENT, COMSOL Multiphysics, Matlab and FlexPDE software packages have been purchased and installed. Other development software includes Fortran and C compliers. The source code software for nine legacy safety analysis computer codes, obtained under an agreement between Ontario Power Generation and McMaster University, have been used to introduce both graduate and summer undergraduate students to safety analysis methodology and reengineering of legacy software. Additional software license agreements have been signed with AECL and students are currently conducting research using the CATHENA, ASSERT, RFSP, WIMS suite of computer codes.

Experimental Facilities

a. The quench heat transfer experimental research facility has been established in collaboration with Dr. M. Hamed of the Department of Mechanical Engineering. Excellent qualitative, quantitative and high speed video image data have been acquired from thermal quenching experiments conducted in this facility.
b. Construction of a water CHF test facility has been completed and experiments have been performed to measure 2-phase heat transfer and pressure drop in water up to 2MPa. A new power supply was funded through Term 1 IRC funds and has provided accurate power up to 128kW. An additional 128kW will be order as part of the CANS facility. CHF and high pressure experiments will be completed in 2010.
c. A scaled Lucite experimental header facility was completed and experiments were performed to measure flow and pressure distribution in CANDU-type inlet headers. Phase Doppler Anemometer (PDA) measurements will be performed using a new facility funded by CFI through the Leaders Opportunity Fund grant to D.R. Novog.
d. A low pressure flow facility for flow and phasic distribution measurements in MNR, CANDU and PWR geometries has been designed and is being constructed by Stern Laboratories (funded by the McMaster Nuclear Reactor) and will be installed at McMaster in 2010.

Research Program

Rapid growth of the research group was achieved with the number of graduate students increasing from to six (6) students at the end of 2005 to twenty-nine (29) working on research projects in the areas of best estimate and uncertainty methods in nuclear safety analysis, heat transfer modeling, severe accident phenomena as well as GEN IV activities (funded separately through NUCLEAR Ontario, AECL, and NRCan programs) by the end of 2009. A total of 11 Masters students have already graduated from the IRC program with 29 students currently enrolled.

Difficulty persists in recruiting a post-doctoral fellow due to the strong employment opportunities in the nuclear industry. To compensate, a large number of undergraduate summer research students have been recruited into the research program which has proved to be of significant benefit in attracting more undergraduate students into the Nuclear Engineering option.

The students and their research topics are listed below.

Ian Hill – *M.Sc. Student*, started September, 2004, Supervisor: J.C. Luxat
Research Topic: Application of BEAU Methods for CANDU Channel Powers.
Completed September 2006 and employed as a Reactor Physicist at AECL, Sheridan Park.

Omar Shaikh – *M.Sc. Student*, started September, 2004, Supervisor: J.C. Luxat
Research Topic: Best-Estimate and Uncertainty Analysis of Reactor Space-time Kinetic Transients in large LOCA.
Completed December 2006 and employed as a Reactor Physicist at AMEC - Nuclear Safety Solutions, Toronto.

Daryoosh Vashaee – *Ph.D. Student*, started November, 2004, Supervisor: J.C. Luxat
Research Topic: Parameter Identification of Space-time Dependent Reactivity in CANDU Reactors
This student withdrew from the program and has taken a junior faculty position at a US university.

Juliana Fetenau – *M.Sc. Student*, started September, 2005, Supervisor: J.C. Luxat
Research Topic: Modelling the Onset of Critical Heat Flux on Horizontal Cylinders

Jintao Jiang – *M.Sc. Student*, started September, 2005, Supervisor: J.C. Luxat
Research Topic: Modelling the Quench Heat Transfer on Horizontal Cylinders
Completed April 2008 and employed at Bruce Power, Bruce site.

Jun Xue – *M.Sc. Student*, started September, 2005, Supervisor: J.C. Luxat
Research Topic: Dynamic Sensitivity Analysis and Uncertainty Propagation of Fuel Element Heat Transfer
Currently employed at Bruce Power, Toronto office.

Fang Bao - *Ph.D. Student*, started September, 2006, Supervisor: D.R. Novog
Research Topic: Best Estimate and Uncertainty Analysis of Small LOCA in CANDU Reactors

Kifah Takrouri – *Ph.D. Student*, started September, 2006, Supervisor: J.C. Luxat
Research Topic: Experimental Study of Quenching of High Temperature Cylinders

Farshad Talebi – *Ph.D. Student*, started September, 2006, Supervisor: J.C. Luxat
Research Topic: Analysis of Fuel Channel integrity with Localized Hot Spots

Kurt Stoll – *M.Sc. Student*, started September, 2007, Supervisor: J.C. Luxat
Research Topic: Development of Trip Parameter Maps for the McMaster Nuclear Reactor
Completed December 2009 and continuing to doctoral studies with J.C. Luxat.

Daniel Pohl – *M.Sc. Student*, started September, 2007, Supervisor: J.C. Luxat
Research Topic: Parallel Channel two-phase natural circulation in CANDU reactors.
Completed September 2009 and employed at AMEC - Nuclear Safety Solutions, Toronto.

Ricardo Perez-Concepcion – *M.Sc. Student*, started September, 2007, Supervisor: J.C. Luxat
Research Topic: Mechanistic model of fuel channel disassembly in CANDU reactors.
Currently employed at AMEC - Nuclear Safety Solutions, Toronto.

Greg Gerle – *M.Sc. Student*, started September, 2007, Supervisor: J.C. Luxat
Research Topic: Analysis of lattice cell physics of CANDU with actinide recycle.

Adam Cziraky – *M.Sc. Student*, started September, 2007, Supervisor: J.C. Luxat
Research Topic: Modeling the contact conductance between two contacting tubes.

Completed September 2009 and employed at AMEC - Nuclear Safety Solutions, Toronto.

Azin Behdadi – *M.Sc. Student*, started September, 2007, Supervisor: J.C. Luxat
Research Topic: Analysis of the thermalhydraulics around a calandria tube following pressure tube contact.
Completed December 2009 and continuing to doctoral studies with J.C. Luxat.

Marko Gocmanac – (AMEC-NSS Employee, Part Time *M.Sc. Student)*, started September, 2008, Supervisor: J.C. Luxat
Research Topic: Hydraulic simulation of Shutoff Rod Insertion.

Ryan Lin – *M.Sc. Student*, started May, 2008, Supervisor: J.C. Luxat
Research Topic: Experimental investigation of boiling heat transfer of downward facing surfaces with local obstacles.

Karol Kozlowski – *M.Sc. Student*, started September, 2008, Supervisor: J.C. Luxat
Research Topic: Analysis of reactor kinetics of actinide burning CANDU

Minhaj Malik – *Ph.D. Student*, started May, 2009, Supervisor: J.C. Luxat
Research Topic: CFD Analysis of Advanced CANDU fuel channels.

Yonni Friedlander – *M.Sc. Student*, started September, 2009, Supervisor: J.C. Luxat
Research Topic: Systems analysis of advanced CANDU fuel cycles.

Ala Muhana – *M.Sc. Student*, started September, 2007, Supervisor: D.R. Novog
Research Topic: Validation of CFD for Inlet Header Flows.
Completed: September 2009.

Brad Statham – *Ph.D. Student*, started September, 2007, Supervisor: D.R. Novog
Research Topic: Critical heat Flux Measurements in Medium Pressure Water.
Completed Masters December 2009. Currently Enrolled in PhD program with D.R. Novog.

Ken Leung – *Ph.D. Student*, started September, 2007, Supervisor: D.R. Novog
Research Topic: CFD of Advanced passive Moderator Systems.
Completed Masters August 2009. Currently Enrolled in PhD program with D.R. Novog.

Ming Hu – *M.Sc. Student*, started September, 2007, Supervisor: D.R. Novog
Research Topic: On-line Compliance methodologies for Best Estimate.

Justin Spencer – *M.Sc. Student*, started September, 2007, Supervisor: D.R. Novog
Research Topic: Intermittent Buoyancy Induced Flow in CANDU channels.

Andrew Morealle – *Ph.D. Student*, started September, 2008, Supervisors: J.C. Luxat D.R. Novog
Research Topic: Coupled Thermalhydraulic and Reactor Physics Analysis of Small Break LOCA.

Matt Ball – *Ph.D. Student*, started September, 2007, Supervisors: D.R. Novog & J.C. Luxat

Research Topic: Propagation of uncertainty in Reactor Physics Simulations.

Ima Ituen– *M.Sc. Student*, started May, 2009, Supervisor: D.R. Novog
Research Topic: Probabilistic Level 2 PSA of a SCWR-CANDU Design (funded under NRCan program)

Katherine Heckman – *M.Sc. Student*, started May, 2009, Supervisor: D.R. Novog
Research Topic: Consequence Analysis of a Severe Accident in a SCWR-CANDU (funded under NRCan program).

Paul Szymanski – *M.Sc. Student*, started September, 2009, Supervisor: D.R. Novog
Research Topic: Coupled CFD-System Code Analysis.

Madhuri Chatharaju – *M.Sc. Student*, started January, 2009, Supervisor: D.R. Novog
Research Topic: IAEA Benchmark of a Heat Transfer in a SCWR CANDU (funded by AECL).

Pouya Sabouri – *M.Sc. Student*, started September, 2008, Supervisor: D.R. Novog
Research Topic: Best Estimate LBLOCA Thermalhydraulic Analysis Using RELAP

David Hummel – *M.Sc. Student*, started May 2008, Supervisor: D.R. Novog
Research Topic: Assessment of Depressurization Transients with the USRC Code TRACE.

Michael McDonald – *M.Sc. Student*, started September, 2008, Supervisor: D.R. Novog
Research Topic: Reactor Physics lattice Cell Analysis of a SCWR-CANDU Core (funded by AECL).

Sarah Mostafian – (AECL Employee, Part Time M.S.C), started September 2008
Supervisor: D.R. Novog
Research Topic: Application of Thermalhydraulic System Codes for CANDU-SCWR Designs (funded by AECL)

A total of twelve (12) undergraduate summer research students successfully completed research projects over the period August 2007 to September 2009 and supervised by the IRC or AIRC.

Interactions with Industrial Sponsors and Collaborations

Both the Chair and Associate Chair have maintained strong interactions with industrial sponsor organizations, UNENE Associate Member organizations, acting as an external consultant and technical reviewer to Ontario Power Generation, Bruce Power, AECL, CANDU Owners Group (COG), Nuclear Safety Solutions Ltd.(NSS), CANDESCO, Kinterics, the CNSC, the International Atomic Energy Agency (IAEA) and other international organizations. These interactions include the following.

Chair (J. Luxat)

- Member of the COG Safety & Licensing Technical Committee, acting as an advisory resource. Participated in the Annual COG/CNSC Safety & Licensing Seminar and the Annual COG S&L program planning seminar.
- Member, Review Panel for Early Researcher Awards, Ministry of Research and Innovation, Government of Ontario. Feb 2008, 2009 & 2010
- Member, OCGS Appraisal Visit Review, Department of Chemistry and Chemical Engineering, Royal Military College, 27-28 April 2009
- Member, Board of Directors, Atomic Energy of Canada, Ltd., Appointed October 2008.
- Member, Science, Technology and Nuclear Oversight Committee of the Board of Directors, Atomic Energy of Canada, Ltd.,
- Government of Alberta, Appointed to Nuclear Power Expert Panel advising Minister of Energy, April 2008.
- Government of Canada, Privy Council Office Panel, April 2008.
- Member, Executive Committee, American Nuclear Society Thermal Hydraulics Division
- Member, Advisory Board, International Association for Structural Mechanics in Reactor Technology (IASMiRT).
- Member, Organizing Committee, SMiRT 20, Helsinki, Finland, 2009.
- General Conference Chair & Chair of Organizing Committee, 14th International Conference on Nuclear Reactor Thermalhydraulics (NURETH-14), Toronto, Ontario, (to be held in 2011)
- Reviewed NSERC grant research proposals and research proposals seeking funding for projects under Canada's GPX program.
- Chair of the UNENE Research Advisory Committee (RAC) for a two year term.
- Ontario Power Generation - Developed and delivered a series of executive level and detailed technical courses on Pressurized Water Reactor (PWR) technology and associated safety issues, 2008.
- Bruce Power -Refurbishment of the Bruce A Units 1 and 2: Analysis of safety system performance under different impairment conditions, and provision of advice and assessments regarding safety design and CNSC licensing issues, 2008-2009.
- COG - Member of an Expert Panel reviewing the modelling of temperature induced deformation of CANDU fuel bundles, 2009.
- COG - Participated in Best Estimate and Analysis of Uncertainty exercise for an RD-14M experiment, 2007-2008.
- CNSC - Participated in an international panel of experts on a Phenomena Identification and Ranking Table (PIRT) process addressing the effects of component and system ageing mechanisms on the results of Probabilistic Risk Assessments (PRA).
- AECL - Reviewed ACR-1000 Severe Accident program and mitigating system design.
- AECL - External Licensing Advisory Group (ELAG) providing independent advice to executive management on licensability of the Advanced CANDU Reactor (ACR-1000) in Canada and in other international jurisdictions.
- AECL - Member, Nuclear Safety Review Committee (NSC) - reviewed the safety of ACR-1000 and providing advice to Chief Engineer.

- AECL - Chair of the Independent Safety Review (ISR) Team - reviewed the acceptability of the safety analysis and the safety case for ACR-1000 and reported to the NSC.
- AECL - External Reviewer, AECL R&D Program, 2008/09
- Provided technical advice regarding nuclear safety and nuclear safety education and training to senior management of KANNUP, the Pakistan Atomic Energy Commission (PAEC) and the Pakistan Nuclear Regulatory Authority (PNRA).

Associate Chair (D. Novog)

- Member – International Expert Panel Review of CANDU Loss of Regulation Extreme Value Statistical (EVS) Methodology, CANDU Owners Group (COG), 2008-2009.
- Reviewer, NRU Safety Factor Review for Life Extension, CANDESCO, 2009-2010.
- Reviewer, Independent Safety Review (ISR) ACR-1000 safety analysis, 2008
- Member, OECD Benchmark Team on Thermalhydraulic, 2008-present.
- Lecturer, Canadian Nuclear Society Reactor Safety Course, 2008-present.
- Member, OECD Reactor Physics Uncertainty Benchmark Team, 2008-present.
- Member, OCGS graduate Scholarships for Ontario Students, 2008-present.
- Consultant to CANDESCO on Deterministic Safety Analysis for NRU.
- Reviewer, Journal of Nuclear Science and Engineering, Journal of Nuclear engineering and Design, 2008-present.
- Organizing Committee, Canadian Climate Change Technology Conference, 2008.
- Reviewer, NSERC and US DOE academic granting programs, 2008-2009.
- Technical Organizing Committee - 2009 CNS Annual Conference, 2010 NUTHOS China, 2010 CCSC Toronto, NURETH 2011 Toronto.
- Consulting services on Nuclear Safety Analysis Issues through NSS to Bruce Power and OPG (2006-present)
- Consultant on Bruce Power Low Void Reactivity Fuel Project, 2007-2008.
- Member of COG Industry Team on Computer Code Strategic Direction, 2007-2008
- Consulting services on Nuclear Safety Analysis Issues through NSS and CANDESCO to Bruce Power, AECL and OPG (2006-present)

Publications for 2007-2009

1. J.C. Luxat (contributing author), *Nuclear Engineering Handbook*, K. Kok (Editor), CRC Press, 2009.
2. A. Morealle and D.R. Novog, “Determination of Operator Action Times During a Loss-of-Feedwater Event Using Extreme Value Statistics”, J. of Nuclear Science and Engineering, in press, Feb. 2010.
3. J. Luxat and D.R. Novog, “A Generalized Failure Map for Fuel Elements Subjected to a Power Pulse”, J. of Nuclear Engineering and Design, in press, 2010.

4. J.C.Luxat, “Thermalhydraulic Aspects of Progression to Severe Accidents in CANDU Reactors”, Nuclear Technology, Vol. 167, No. 1, pp 187-210, July 2009.
5. D Vashaee, L Tayebi and J Luxat, “Reference Model Parameter Identification of Space-Time Dependent Reactivity in a CANDU-PHWR”, Annals of Nuclear Energy, 35 (2008) 228–237.
6. K. Leung, A. Petruzzi, D.R. Novog and, F. D’Auria, “Modelling of Phase Distribution for the BFBT International Standard Problem Using RELAP5-3D”, J. of Nuclear Engineering and Design, in press, March 2010.
7. D.R. Novog, R. Judd, J.S. Chang, “Characteristics of Onset of Nucleate Boiling Hysteresis of Freon 134a Flow in a Tubular Channel”, accepted for publication in International Journal of Thermal Sciences (accepted with revisions, in progress), 2009.
8. A. Muhana and D.R. Novog, “Validation of FLUENT for Flow Predictions in a Scaled CANDU Inlet Header”, in preparation for the Nuclear Technology, 2010.
9. K. Leung and D.R. Novog, “ASSERT Prediction Accuracy of the Critical Power in a BWR Fuel Array”,to be submitted to the J. of Nuc. Eng. and Design, 2010.
10. K. Takrouri, J. Luxat, M. Hamed and A. Hassan, “Heat Transfer and Two Phase Flow Behavior during Quench of Hot Horizontal Cylindrical Tubes”, ASME Conf., November 2009.
11. A. Behahdi and J.C. Luxat, “2D Modeling of Moderator Flow and Temperature Distribution Around a Single Channel After PT/CT Contact” , Proc. 30th Annual Canadian Nuclear Society Conference, Calgary, Alberta, May 31-June 3, 2009.
12. F. Talebi and J.C. Luxat, “Heat Transfer Modeling of CANDU Pressure Tube Under Localized High Temperature Condition” , Proc. 30th Annual Canadian Nuclear Society Conference, Calgary, Alberta, May 31-June 3, 2009.
13. A. Cziraky and J.C. Luxat, “A Mechanistic Model for Pressure Tube-Calandria Tube Thermal Contact Conductance for a Pressure Tube Ballooning Event” , Proc. 30th Annual Canadian Nuclear Society Conference, Calgary, Alberta, May 31-June 3, 2009.
14. K. Takrouri, J. Luxat, M. Hamed and A. Hassan, “Heat Transfer and Two Phase Flow Behavior during Quench of Hot Horizontal Cylindrical Tubes”, 4th International Conference on Thermal Engineering, Abu Dhabi, January 2009.
15. A. Morealle and D.R. Novog, “The Application of Extreme Value Statistics to Safety Analysis and Trip Assessment”, International Atomic Energy Agency - Technical Meeting on Application of Deterministic Best Estimate Safety Analysis, Italy, 2009.
16. K. Leung, A. Kovtonyuk, A. Petruzzi, F. D’Auria, D. Novog, “Prediction of Void Fraction Uncertainty Bands in BWR Fuel Bundles Using the CIAU Methodology”, International Conference on Advances in Mathematics, Computational Methods, and Reactor Physics, New York, 2009.
17. A. Muhana and D.R. Novog, “Validation of Computational Fluid Dynamic Tools for Prediction of Single-Phase Flow Distribution in CANDU Headers”, Proc. Of the Canadian CFD Society, 2009.
18. D. Hummel and D.R. Novog, “Study of TRACE Depressurization Predictions Against Experimental Data Across Different Scales”, Proc. of NURETH-13, Japan, 2009.

19. D.R. Novog and F. Hoppe, “An Engineering Primer on Extreme Value Statistics”, Proc. Of the Canadian Nuclear Society, 2009.
20. A. Morealle and D.R. Novog, “The Application of Extreme Value Statistics to Safety Analysis and Trip Assessment”, International Atomic Energy Agency - Technical Meeting on Application of Deterministic Best Estimate Safety Analysis, Italy, 2009.
21. D.R. Novog and P. Sermer, “A Statistical Based Methodology for Establishing Safety System Setpoint for Nuclear Reactors”, Science and Technology of Nuclear Installations, 2008.
22. J.T. Jiang and J.C. Luxat, “Modeling Pool Film Boiling and Quench on the Outer Surface of a Calandria-Tube Following a Critical Break LOCA in a CANDU Reactor”, Proceedings Int. Youth Nuclear Congress (IYNC 2008), Interlaken, Switzerland, September 2008.
23. D. R. Novog and K. Leung, “Benchmark of Numerical CFD Studies of Phase Distribution in Two-Phase Boiling in a Swirl-flow Channel Against and Experimental Heat Transfer and Phase Distribution Data”, Journal of Heat Transfer Engineering, August 2008.
24. O.J. Shaikh and J.C. Luxat, “Comparison of LOCA Power Transient Uncertainty Analysis Methods” , Trans. American Nuclear Society Annual Conference, Anaheim, California, June 2008.
25. J.T. Jiang and J.C. Luxat, “Modeling the Quenching Of a Calandria Tube Following A Critical Break LOCA In a CANDU Reactor”, Proceedings 29th Annual Canadian Nuclear Society Conference, Toronto, Ontario, June 2008.
26. J.C. Luxat, “A Technical Basis for the Flux Corrected Local Conditions Critical Heat Flux Correlation”, Proceedings 29th Annual Canadian Nuclear Society Conference, Toronto, Ontario, June 2008.
27. J.C. Luxat and D.R. Novog, “Heat Transfer Limitation during Rapid Depressurization”, Proceedings 29th Annual Canadian Nuclear Society Conference, Toronto, Ontario, June 2008.
28. D.R. Novog, P. Sermer, D. Quach, J.C. Luxat, “Determination of Realistic Margins to Fuel Heatup for Slow Loss of Regulation Accidents in a CANDU Reactor”, Proceedings 29th Annual Canadian Nuclear Society Conference, Toronto, Ontario, June 2008.
29. J.C. Luxat, “Dynamic Sensitivity Analysis of Thermal-Mechanical Deformation of a CANDU Fuel Channel”, Proceedings ICONE 16, Orlando, Florida, May 2008
30. D.R. Novog, “Probabilistic Analysis of Derived Safety Acceptance Criteria for CANDU Reactors”, Transactions of the American Nuclear Society, Vol. 99, 2008.
31. J.C.Luxat and D. Novog, “A Generalized Failure Map for Fuel Elements Subject to a Power Pulse”, Proc. 19th SMiRT Conf., Toronto, Ontario, August 2007
32. D. Luxat and J.C.Luxat, “Evaluation of Failure Modes of CANDU Calandria Vessels Under Severe Accident Conditions”, Proc. 19th SMiRT Conf., Toronto, Ontario, August 2007
33. J.C.Luxat, “Thermalhydraulic Aspects of Progression to Severe Accidents in CANDU Reactors”, Proc. 12th International Meeting on Nuclear Reactor Thermalhydraulics (NURETH-12), Pittsburgh, Pennsylvania, September/October 2007.
34. D.R. Novog and F. Bao, ”Thermalhydraulic Parameter Ranking and Best Estimate Analysis of Loss of Forced Circulation Accidents in a CANDU

Reactor", 12th International Meeting on Nuclear Reactor Thermalhydraulics, 2007.

35. D. Luxat and J.C.Luxat, "Parametric Analysis of Fuel Cooling in LOCA with ECCS Impairments in CANDU Reactors", Trans. 2007 American Nuclear Society Annual Meeting, Boston, Massachussets, June 2007.
36. J.C.Luxat, "Reactivity Initiated Accidents and Loss of Shutdown – 20 Years Later", Proc. 28th CNS Annual Conf., Saint John, New Brunswick, June 2007 (also Bulletin of the Canadian Nuclear Society).

<u>To be published</u>

37. A. Morealle. W. Garland and D.R. Novog, "Analysis of a Preliminary Fuel Design for Actinide Burning in a CANDU Reactor", accepted for Proc. of American Nuclear Society - PHYSOR-10, Pittsburgh, 2010.
38. M. Ball, C. Parisi, D.R. Novog, F. D'Auria. "Uncertainty in Physics Calculations due to Resonance Cross Section Uncertainty", accepted for Proc. American Nuclear Society - PHYSOR-10, Pittsburgh, 2010.
39. K. Heckman and D.R. Novog, "Differences in Severe Accident Behaviour and Phenomena in a CANDU-SCWR", submitted to the 2nd China-Canada International Workshop on SCWR Technologies, 2010.
40. I. Ituen and D.R. Novog, "Application of Regulations to Generation IV Reactor Designs in Canada", submitted to the 2nd China-Canada International Workshop on SCWR Technologies, 2010.
41. M. Macdonald and D.R. Novog, "Analysis of CANDU-SCWR Reactor Physics Characteristics with WIMS and SCALE", submitted to the 2nd China-Canada International Workshop on SCWR Technologies, 2010.
42. J. Spencer, A. Tahir, and D.R. Novog, "Analysis of Intermittent Boiling Induced Flow in a CANDU Reactor", submitted to NUTHOS-10, Shanghai, China, October, 2010.
43. F. Bao, D.R. Novog, and J.C. Luxat, "Realistic Assessment of a Small Break Loss of Coolant Accident in a CANDU Reactor", submitted to NUTHOS-10, Shanghai, China, October, 2010

<u>Other Presentations</u>

Chair (J. Luxat)

Invited

1. J.C. Luxat, "*Multiphysics Software and the Challenge to Validating Complex Physical Models*", Plenary Presentation, 23rd Nuclear Simulation Symposium, Ottawa, Ontario, 2008 November 2-4.
2. J.C. Luxat, "*Verification and Validation of Analysis Software for Nuclear Safety and Engineering Applications*", Topical Workshop on Identifying Structural Issues in Advanced Reactors, Porvoo, Finland, Nov 5-6, 2008.
3. J.C. Luxat, "*Canada's Nuclear Power Program: Status and Developments*", Penn State University, April, 2008.
4. J.C. Luxat, "*Thermalhydraulic Aspects of Progression to Severe Accidents in CANDU Reactors*", Invited Keynote Lecture, <u>12th International Meeting on</u>

Nuclear Reactor Thermalhydraulics (NURETH-12), Pittsburgh, Pennsylvania, September/October 2007.
5. J.C. Luxat, *Nuclear Education in Canada*, presentation at Canadian/Chile Seminar on Nuclear Energy in Canada, Santiago, Chile, Nov 2009.
6. J.C. Luxat, *Nuclear Energy: Public Perception and Policy*,(invited) lecture to McMaster Alumni Association, Hamilton, Ontario, Oct. 2009
7. J.C. Luxat, "*Nuclear – A Safe, "Green Energy" Option*", Presentation to Norfolk-Haldimand Municipal Council, McMaster University, August 30, 2007.
8. J.C. Luxat, "CANDU Severe Accidents", University of Pisa Seminar and Training on Sensitivity, Uncertainty and 3-D Coupled Calculations in Nuclear Technology (3-D S.UN.COP), Hamilton and Niagara Falls, 8-26 October, 2007.

Associate Chair (D.R. Novog)
Invited

1. "Safety Research Related to the Supercritical Water CANDU Reactor", Invited presentation at the NRCAN National Workshop on SCWR Program, October, 2009.
2. "R&D Challenges for Super Critical water Reactors", Next Generation Nuclear Reactor (NGNR) Forum, Petten, Netherlands, 2009.
3. "Super Critical Water Reactors as part of the Generation IV International Forum (GIF)", Invited presentation at the GEN-IV Reactor Training Forum, Netherlands, October 2008.
4. Key Note Address, "The Importance of Safety in the Nuclear Renaissance", Young Generation Nuclear Congress (IYNG), Interlaken, Switzerland, Sept. 2008.
5. "Comparison of Depressurization Characteristics for Systems Containing Water Below the Supercritical Pressure to Identical Systems Below the Supercritical Condition", Proc. of the China-Canada Joint Workshop on Supercritical Water Reactors, Shanghai, China, April 2008.
6. "Safety Considerations and Research for GEN-IV Nuclear Reactors", Invited presentation at the Canadian GEN IV Workshop, August 20, Ottawa, 2007.