Industry–University Collaboration for Research and Education

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Abstract

University Network for Excellence in Nuclear Engineering also known as UNENE is a joint partnership between the nuclear industry and thirteen universities. UNENE has been legally registered as of 2002 as a not for profit organization. The establishment of this network was prompted by industry to address anticipated retirement of a large number of professionals from industry starting in early 2000 onwards and thus the loss of nuclear knowledge and experience within industry. UNENE was created to provide a sustainable supply of highly qualified personnel to industry, support nuclear research within various universities and provide a course based Master's Degree in nuclear engineering to enhance the knowledge of young professionals within the industry in the science and technology of the CANDU nuclear power system. The paper describes the current UNENE, its research objectives, key outcomes of research programs to date and its contribution to industry needs in maintaining an economic and safe power plant performance of its nuclear fleet. The paper addresses achievements within the education program and the new 4-course diploma program recently introduced to enhance core expertise of young industry professionals. Also publications and national and international collaborations in various aspects of research have significantly contributed to Canada`s position in nuclear science and research worldwide. Such collaborations are also addressed.

1. Introduction

The start of the new millennium prompted the nuclear industry to review its intellectual and technical capability and plan for the future to meet its business priorities. The operating utilities' priority is maintaining their core capabilities to secure support of the design and licensing basis of the current CANDU Nuclear Power Plant (NPP) fleet. Along with this priority, design and vendor organizations plan to maintain their core technical capabilities for the support of their current design and refurbishment contracts, as well as the medium and long term need for the continuous evolution of the technology in keeping with new market and regulatory requirements. This became the impetus for the establishment of an industry-academia collaborative framework called UNENE; University Network for Excellence in Nuclear Engineering.

To date, more than a decade in existence, this partnership has grown and steadily progressed to become a mature and well respected partnership with notable achievements. These are in both program areas, Research and Education, and are discussed further in the paper under

- Leveraged funding
- Research outcomes and advances in knowledge
- New Equipment and Research facilities established under UNENE

- Education Program ; Knowledge transfer mechanisms to enhance nuclear competencies within young industry professionals
- Training and development of Highly Qualified Personnel for industry and other scientific agencies within Canada
- Publications by UNENE funded researchers

2. Leveraged Funding

Industry research funding is 100% leveraged by NSERC to the level of $1.67M per year. Additional leveraging of research funds continues amounting to an additional $1M through individual efforts by researchers at various UNENE universities (e.g. McMaster, RMC, UWO etc.). In addition a number of one-time grants totalling $43M were secured through multi UNENE university submissions during the two year period 2007-2009. These grants were mainly from provincial and federal sources such as Ontario Research Funds (ORF), NSERC and Canadian Fund for Innovation (CFI), and some Universities. These additional funds enabled new facilities to be established, hence sustaining an increased scope of research and number of graduate students. The new equipment and research facilities established are discussed further in this paper.

3. Research Outcomes

To date research outcomes have been mostly advances in knowledge in support of continued safe and economic performance of plants and/or development of a methodology, software or hardware for potential application to plant operation and safety margin enhancements or towards optimization of inspection and maintenance practices. Some of the notable outcomes are:

1- Severe accident phenomena modelling and analysis with validation through experimental results. This work continues and is in support of substantiating limits of In Vessel Retention (IVR) for CANDU cores. The IVR is the basis of severe accident mitigation for current and future CANDU plant designs and licensing. Along with the ongoing research in this area, an optimized heat sink mitigation strategy is formulated crediting and confirming current plant heat sinks.

2- Operating margin quantification and restoration through the application of advanced thermalhydraulic modelling and experiments. These are undertaken to substantiate margins in plants that are close to refurbishment. Experimental CHF (Critical Heat Flux) facility for full characterization of CHF under high pressure and high temperatures are also being used covering reactor conditions to improve modelling in support of margin quantification.

3- Application of a probabilistic based methodology to derive a risk based inspection and maintenance program for critical NPP equipment. This methodology is developed under the UNENE Research Chair program at the University of Waterloo. It has been applied successfully to other key plant components industry wide in support of a risk based inspection and maintenance program for some of these components. This methodology integrates actual component inspection data and mechanistic models on component degradation mechanisms into a probabilistic based methodology to derive a risk based approach to component replacement or maintenance.

4- Research data from the Nuclear Materials Program of Queen`s University research chair, is used by industry for validation of the Fitness For Service Guidelines (FFSG) codes used for Fuel Channel Inspection.
5- Fuel-channel creep models are also updated by industry based on new understanding developed by the Nuclear Materials IRC.

Other ongoing research that will result in advances in knowledge and of potential benefit to future operation and refurbishment are:

a) Improved understanding of long-term radiation impact on non-human biota. This is based on current research on fish species undertaken by the Research Chair on Radiation Physics and Environmental Safety at UOIT.
b) ALARA (As Low As Reasonably Achievable) improvements for equipment maintainability is expected based on an ongoing development of a robot (at UOIT) equipped with radiation detectors and 3D mapping of rooms/areas along with a capability of identifying hot spots in such areas to reduce/optimize dose and durations during maintenance.
c) Recommendation on the corrosion susceptibility of Steam Generator Tubing (Alloy 800 and 600) under various operating and shutdown conditions for avoidance of potential corrosion during various conditions.
d) Development of a Transient Eddy Current (TEC) probe technology for inspection of equipment internals with tight configurations such as those of SG tube-tube support area, Pressure Tube/Calandria Tube gap (PT/CT gap) and CT/ LISS (SDS2) nozzle gap.

4. New Equipment and Research Facilities

Leveraged one-time funds from federal and provincial agencies have been used towards the establishment of new research facilities in universities and the acquisition of modern equipment to sustain an increased scope of research and number of graduate students. Some notable facilities are

-The Reactor Material Testing Lab (RMTL) at Queen`s University

This new facility now built and operational has a 4 MV tandem proton accelerator, two new electron microscopes and other testing equipment. The proton accelerator will be used to introduce degradation into fuel channel materials at the microstructure level, simulating radiation and stress introduced as a result of in-reactor conditions and to further characterize key degradation mechanisms experienced in materials, as well as investigating potential modification and improvements of materials. These results will be used to expand our understanding of CANDU fuel channel materials, and increase our capability to characterize their irradiation induced degradation mechanisms. Funding to establish the facility was obtained from the Canada Foundation for Innovation (CFI), the Ontario Ministry of Research and Innovation (MRI) and Queen's University.

Figure 1: Schematic of the Reactor Material Test Lab (Queen`s University)

- A new Centre for Advanced Nuclear Systems (CANS). This $24M regional facility provides a unique world-class capability to advance research in three focus areas:

1) Nuclear materials,
2) Nuclear safety thermalhydraulic behaviour, and
3) Health physics.

Funding to establish the facility was obtained as grants awarded in 2009 by the Canada Foundation for Innovation (CFI) – New Infrastructure Fund (NIF) and the Ontario Ministry of Research and Innovation (MRI).

CANS is comprised of four primary facilities, namely:

1. Post Irradiation Examination of Nuclear Materials (McMaster University)
2. Nuclear Materials Characterization Facility (McMaster University)
3. Thermal Testing Facility (McMaster University)
4. Health Physics Dose Response Facility, located at the University of Ontario Institute of Technology (UOIT) and made fully operational by the IRCs and their team.

These facilities provide a suite of irradiated material handling and testing facilities and equipment; a thermal testing laboratory (at McMaster); and a radiation dose laboratory (at UOIT). This infrastructure, together with the McMaster Nuclear Reactor and the Canadian Centre for Electron Microscopy, provides a world class materials and thermal testing centre unique in North America. The project was supported by a majority of Canadian nuclear energy related companies (OPG, Bruce Power, AECL, and Kinectrics) as well as a number of leading international organizations (EPRI, EdF, Bechtel).

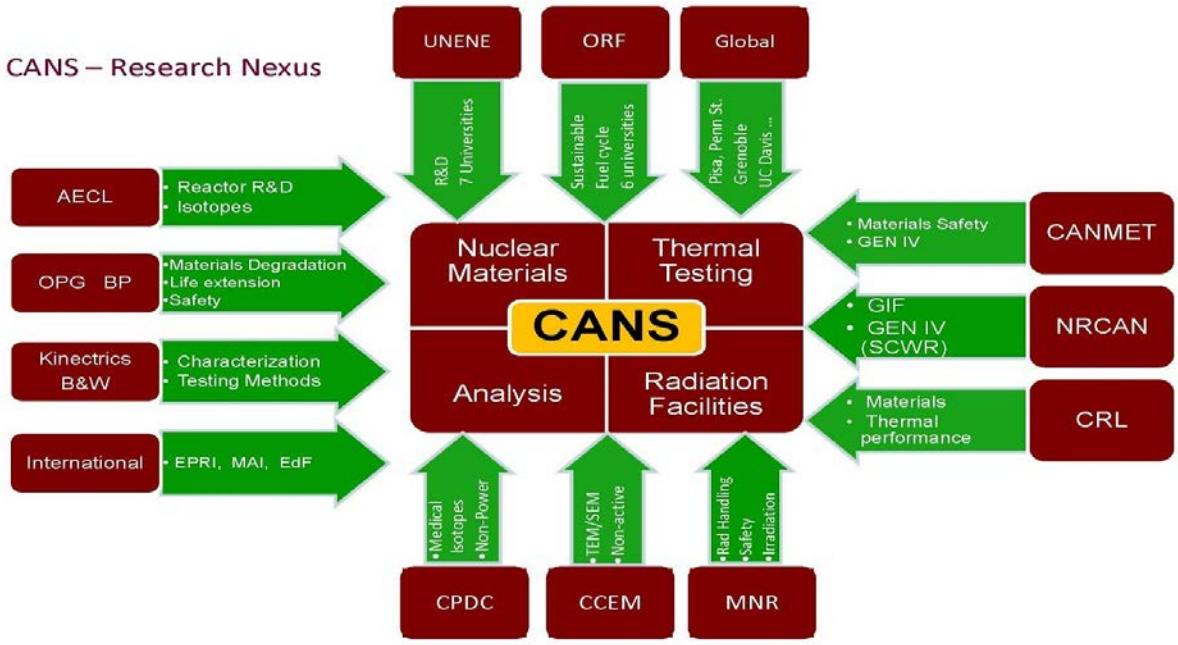

Figure 2: Centre for Advanced Nuclear Systems

5. Education Program

To meet the set objectives for UNENE an education program was initiated 2 years after the establishment of the partnership and following the formal accreditation of the program. The program consists of a course-based M.Eng. in Nuclear Engineering offering graduate level courses from various UNENE universities under the UNENE umbrella. The degree is geared to young industry professionals for enhancing their knowledge of the design and licensing basis of the CANDU technology. Courses cover the entire spectrum of the technology and are offered via different universities with Instructors, mainly UNENE research Chairs that are well recognized scientists in their field with most of them with significant experience in industry as well.

Lectures are delivered in a classroom setting on weekends and use distance-learning tools (Blackboard – Collaborate) to accommodate students at various sites and weather conditions. Since the start of the M.Eng. Program, a total of ninety three (93) students have graduated upon successful completion of the 10-course program or an 8-course plus a project. Figure 3 below provides further details.

A new Diploma program is now introduced under UNENE, starting April 2015. This was the outcome of a strategic planning session of the Board of Directors in March 2011. Its intent is to increase the student base and provide another shorter track in nuclear education. The Diploma is a four (4) graduate-course program enabling young industry professionals to acquire focused knowledge in a given core competency area needed by the individual in his/her current area of responsibility.

Another notable highlight in education is the development of a CANDU Textbook documenting the scientific basis of the CANDU-HWR technology. This was initiated in 2012 under a Joint Project funded under COG (CANDU Owners Group) with contributions from CANDU utilities in Canada and offshore and UNENE. Many chapters of the textbook are now available at www.unene.ca/publications.

Figure 3: Student throughput of the UNENE M.Eng.

6. Development of Highly Qualified Personnel (HQP)

Training and development of HQP for potential deployment by industry is one key objective of UNENE. The complement of graduate students in the various UNENE research programs grew from the early years to a typical level of nearly 130 students who are at various phases of their research programs. Some of the past graduates have been successfully recruited by industry, national laboratories, government and academia within Canada. The bar chart below (Figure 4) depicts a typical distribution of HQP in different research programs.

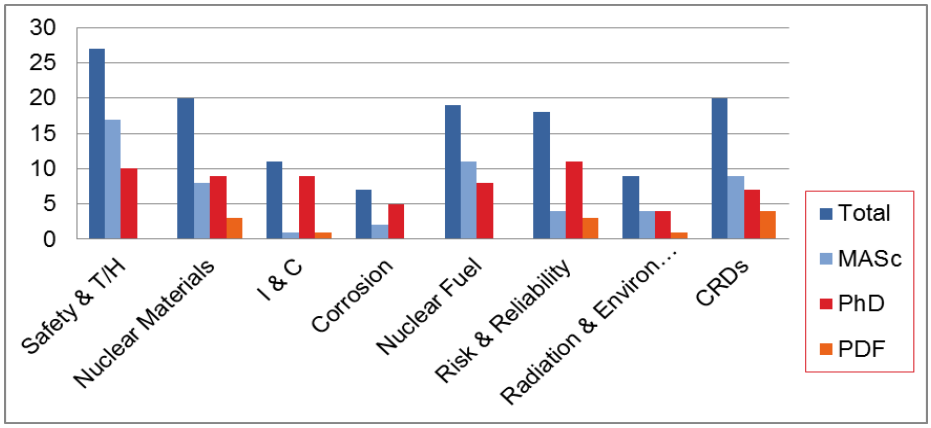

Figure 4: Distribution of HQP across Research Programs (Typical)

7. Publications

Advances in knowledge and technology are documented in Ph.D. and M.A.Sc. theses, as well as journal publications and conference papers. Over 100 publications a year are published in journal papers, conference proceedings, academic /industrial presentations and /or chapters in technical books. These advance knowledge in all aspects of the technology and showcase Canadian nuclear research. These outcomes are also documented nationally through the research Chair participations on various COG technical committees and internationally through various exchanges of students, sabbaticals, etc.

Conclusion

The UNENE Industry-University partnership has steadily grown over the last eleven years, thriving and achieving the following attributes:

1 - Research of relevance and impact in nuclear science and technology and for the benefit of the CANDU design, licensing and operations.
2 - A pool of university-based nuclear experts who are well respected and have a strong research culture of scientific enquiry/innovation.
3 - M.Eng. & Diploma degrees catering to young industry professionals and geared to enhancing core competence.
4 - Extensive national and international collaborations
5 - New research infrastructure (equipment/labs) through leveraged grants from government agencies.

Acknowledgments

The successful partnership of UNENE hinges on the annual financial support of industry members, National Science Engineering and Research Council (NSERC), and on the one-time grants from government agencies such as Ontario Research Funds (ORF), New Infrastructure Fund (NIF), the Ontario Ministry of Research and Innovation (MRI), the Canadian Fund for Innovation (CFI), and some Universities.

References

[1] B. Shalaby, V. Snell, B. Rouben, “UNENE; An Update on Nuclear Education and Research”, in Proceedings of the 31st Canadian Nuclear Society Conference, 2010 June, Montréal, Québec, Canada, 2010 May 25-28
[2] http://www.unene.ca/