UNENE Benefit Report

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Executive Summary

This report notes the benefits of UNENE to its industry partners w.r.t. achieving the three objectives set when established back in 2002 .The objectives assessed are the establishment of research programs in key areas of importance to industry, supply of Highly Qualified Personnel (HQP) to meet industry needs and the creation of a pool of scientific experts for consultation by industry and government when required.
The review covers the last two fiscal years 2007 to Sept 2009 and has identified many benefits of which some of the notable ones are;

1 - UNENE through its IRCs and research programs has succeeded in **leveraging with NSERC/UNENE programs some additional funding of ~$43M from provincial and** federal research and innovation agencies. These have enabled the establishment of new facilities with state-of-the-art equipment and thus increasing the scope of research and size of research teams.

2 - Ongoing **research programs** continue to advance knowledge in all areas of the technology, with some developed technologies successfully deployed by utilities in support of their safe and economic NPP operation;

- A successful example is the application of risk-based methodologies to Life Cycle management (LCM) issues. These, when applied to feeder replacement have reduced the number of feeders requiring replacement by nearly 70 feeders, reducing the cost of such replacement by millions.
- Advanced development of new safety analysis methodologies continue in the area of Best Estimate methodology, as well as advanced Thermal hydraulics in support of phenomena characterization, modeling and code validation. This in the future if adopted as a methodology will reduce some excessive conservatism applied in analysis methodologies.
- Research on effects of manufacturing on PT properties, textures and creep characteristics, continue on current and future PT alloys.
- Advanced Fuel research and increased knowledge are also noted in the report, with outcomes reflected in various code developments, assistance to utilities on fuel performance analyses and on-line fuel defect monitoring. All such results are readily transferred to industry via COG reports. Other research theses are ongoing on ACR fuel and the ability for actinide burning in multispectral CANDU cores etc. The outcomes of fuel cycle studies continue to be of interest to current and future Candu countries.
- The IRC established in UWO has built an advanced Control and Instrumentation lab in 2009, with six projection monitors mimicking NPP human-machine interface with full connectivity to NPP control systems. The lab is used for application development /validation of numerous advanced diagnostic tools and control technologies aimed at reducing the number of safety system channels and common mode failures.
- The IRC at UOIT established on Sept 2008 is in the early phase of identifying dosimetry gaps and establishing research facilities to address them. Two gaps in

dosimetry devices have so far been identified, along with initiating development of two candidate devices aimed at ALARA improvements.

3 - Training and **development of HQP** through research and education continue to yield high caliber graduate students who upon successful completion of their theses have been recruited by industry partners and other institutions, such as universities and government.
As of Sept 2009, the current complement of graduate student in the research program UNENE wide are reported to be over 130 graduate students, as shown in Figure 1 of the report.
The number of MASc and PhD students that graduated during the same period amount to twenty six (26) MASc and twenty five (25) PhD graduates.
Sixty percent (60%) of the Masters graduates were hired by industry partners, whereas thirty two percent (32%) of the PhD graduates were attracted by industry. AMEC-NSS was the most successful UNENE partner in hiring the new graduates, followed by AECL and Bruce Power.

4 - On the aspect of **industry consultation**, over 90 industry interactions /consultations and technical exchanges have been reported in the last two years by all UNENE universities. Most of these were on COG technical committees, industry technical panels and review teams, as well as with various federal and provincial departments and panels. Some of the notable ones are noted in Section 3 of the report.

5 -The **UNENE education program** has also experienced an increased enrollment in the last two years. There are currently 52 active students in the M.Eng program .The program is also gaining credibility as a means of competency building (for career advancement), and knowledge transfer and preservation to young industry professionals. Up to now, thirty seven (37) students have graduated from the M.Eng program out of 103 enrolled. Most of the students in the M.Eng program are from OPG. It is expected that the new Distance Learning tools, currently in use for course deliveries, will entice students from distant sites such as BP, the CNSC and CRL to enroll. New courses are being added to the program, along with more courses being offered on a quarterly basis.

In summary this review confirms that such industry –university partnership has been a good strategic move and has served both parties well in so far as meeting all objectives set forth at the inception of UNENE. Research outcomes continue to advance knowledge in all facets of the technology and support continued safety and economic performance of NPPs in Canada. The supply of HQP has been key in addressing the demographic gaps experienced by industry in the last few years.

1.0 Introduction

This report examines the value derived by the industry partners from the UNENE research and education programs with focus on the last two fiscal years 2007 to September 2009.

UNENE was established in 2002 as a partnership between industry and universities with the objectives of:

- Establishing university research in key areas of interest to industry
- Developing a sustainable supply of HQP to address industry needs
- Providing independent scientific expertise for public and industry consultation

The report will examine the value of research w.r.t. advancement of knowledge, and its benefit to industry and supply of Highly Qualified Personnel to meet industry needs.

The education program of graduate level course M. Eng degree will also be reviewed.

2.0 Value of Research

UNENE research programs were established by nominating well respected industry scientists to different universities to act as “anchors “ for establishing research programs in the following areas of the nuclear technology:

- Nuclear Safety Analysis & Thermal hydraulics
- Nuclear Fuel technology
- Nuclear Materials
- Corrosion and Material Performance in NPP systems
- Risk-Based Life Cycle Management (LCM) of NPP systems
- Control& Instrumentation and Electrical systems
- Health Physics and Environmental Safety

The establishment of these Industrial Research Chairs (IRCs) served as the nucleus of what are now well established research programs, teams and facilities. The outcomes discussed below are advances in nuclear knowledge, training and development of highly qualified personnel (HQP) and leveraging additional funding used to establish state-of-the-art labs and equipment.

2.1 Leveraging Additional Funding and knowledge

Successful leveraging of additional funds amounting to ~ $43 M had been achieved through UNENE universities in the past two years. These were mainly from provincial and federal sources such as Ontario Research Funds (ORF), NSERC and Canadian Fund for Innovation (CFI). The additional funds enabled

new facilities to be established, hence sustaining an increased scope of research and number of graduate students.

2.2 Equipment and Research Facilities

Additional funds enabled the following facilities to be established

a) A High Performance Computing Centre (HPC) was acquired by the Nuclear Safety Research group in McMaster, enabling the coupling of safety analysis codes and code development. Acquisitions were also made of many new safety codes (e.g. FLUENT, COMSOL, Multi physics, MATLAB, etc) along with current CANDU safety codes from Industry Partners (OPG, AECL) for students' research and reengineering of legacy software. A new water CHF facility was also constructed at McMaster University to study steady state and transient Critical heat Flux in support of Industry efforts to disposition CNSC GAI -144

b) A Nuclear Material Testing (NMT) Lab is under planning at Queen's U, with commission expected in 2012. This is in addition to the creep laboratory established at Queen's during the first terms of the IRC program. The project to build the NMT lab is being funded mainly through CFI, Queen's and other provincial funding noted in section 2.1. The new facility will comprise a new building, a 4 MV tandem accelerator, two new electron microscopes and other testing equipment.

c) A new control & Instrumentation lab was established 2009 at the University of Western Ontario (UWO) though its IRC (Professor J. Jiang. Six large projection displays and an operator console have been set up mimicking a full digital human machine interface of an NPP and with full connectivity to existing I&C systems, including smart sensor development systems and wireless monitoring modes for application development to CANDU plants.

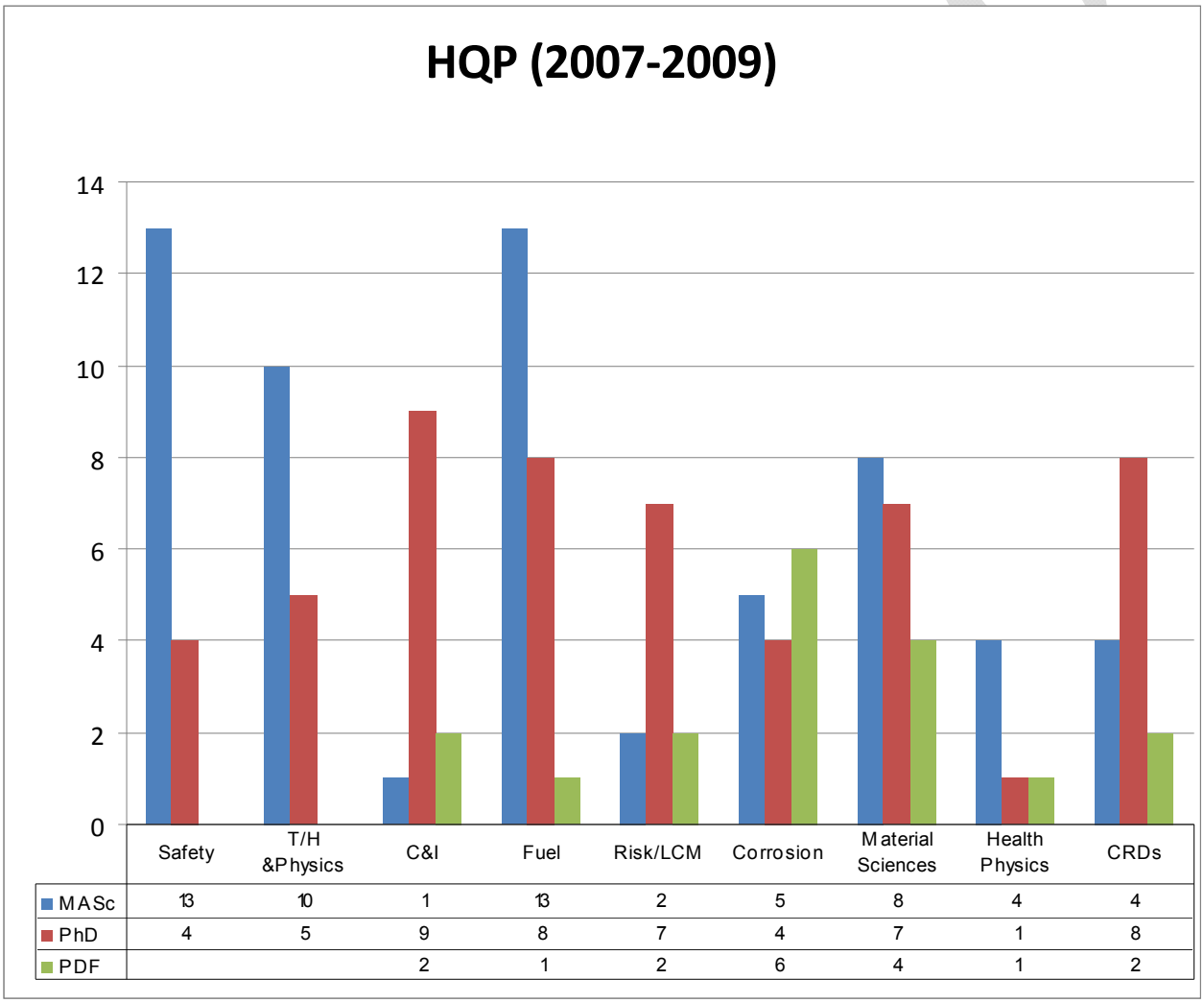
d) Other new facilities were also set up to support ongoing UNENE research programs that could be used in the future by Industry partners towards other research needs .These are ; a water CHF facility , a scaled Lucite experimental header facility (both at McMaster), autoclaves for corrosion studies and state-of-the-art surface analysis and electron microscopy facilities (at U of T)and a Thermogravimetric Analyzer (TGA) for high temperature (2400C)nuclear fuel material studies at RMC

e) Future Facilities:
Joint university efforts continue (under the leadership of IRC (Dr. J. Luxat) in seeking funding for a future Centre for Advanced Nuclear Systems (CANS). This facility is envisaged to provide a suite of irradiated material handling and testing equipment and a thermal testing laboratory (at McMaster) and a dose lab (at UOIT). This infrastructure coupled to the

McMaster Nuclear Reactor and the Canadian Center for the Electron Microscopy will provide a world class materials and thermal testing center unique in North America.

2.3 Training and Development of Highly Qualified Personnel (HQP)

Current UNENE universities report approximately 130 graduate students who, through their research and training, are expected to develop into HQP for potential employment by industry partners. Figure 1 provides such details.



	Safety	T/H &Physics	C&I	Fuel	Risk/LCM	Corrosion	Material Sciences	Health Physics	CRDs
MASc	13	10	1	13	2	5	8	4	4
PhD	4	5	9	8	7	4	7	1	8
PDF			2	1	2	6	4	1	2

Figure 1: UNENE sponsored research students currently in program (Industrial Research Chairs and Collaborative Research and Development grants)

Moreover In the past 2 years (2007-2009) many of the student graduates from the UNENE programs have been recruited by industry partners or by others, such as government, universities etc.

Out of twenty six (26) MASc graduates fifteen of them have been hired by industry making a 58% success in attracting these graduates to opportunities within industry partners.

For PhD graduates, from a total of twenty five (25) graduates eight (8) have been hired by industry partners making the success rate over 30%.

Table 1 & 2 below provide additional details

Table 1
HQP Graduated/Hired by Industry

	MASc		PhD	
	Graduated	Hired by Industry	Graduated	Hired by Industry
Safety & T/H	12	6	--	--
I & C	1	1	2	1
Nuclear Materials	2	1	7	4
Risk – LCM	7	6 (total including PDF PhD)	5 + 5 PDF	(6)
Fuel	2	--	3	1
CRDs	2	1	2+ 1 PDF	1+ 1PDF
Total	26	15	25	8

Table 2
Details of HQP hired by Industry

	Safety & T/H	I & C	Nuclear Materials	Fuel	Risk	CRDs
A-NSS	3 MAScs		3 PhD	--	3	1PhD,1MASc
AECL	1 MASc	1 PhD	1 PhD + 1MASc	--	2	1 PDF
BP	2 MAScs					
OPG		1 MASc				
CNSC				1 PhD		
Kinetrics					1	
Non Industry members		1 PhD (UOIT)	3 PhD	2 PhD 2MASc	8	3
Total	6	3	8	5	14	6

2.4 Advances in Nuclear Knowledge and Technology Transfer to Industry

Established research programs in member universities bring a wealth of knowledge to the industry, while expanding the R&D base beyond the currently established ones within industry. This framework of university/industry cooperation aligns Canada with other nuclear technology exporting countries such as the U.S., France, Russia, South Korea and China. In addition it brings advances in the following knowledge area:

2.4.1 Advances in Nuclear Materials

The focus of research at Queen's has been to increase knowledge of PT material over a wide range of textures and microstructures. Current focus is on the effects of manufacturing parameters on PT properties, textures and creep characteristics of current and future alloys. The current IRC (Prof. R. Holt) continues to have a strong interaction with Industry sponsors, where research results are incorporated into industry/COG reports and other publications. Notable examples are:

a) Two collaborative COG projects with Kinetrics were used to transfer technology relating to FC Fitness-for-Service Guidelines (FFSG) from research program to industry

b) Other joint industry reports include assessment of PT in-service deformation and a SOTAR (State-of-the-Art Report) prediction on PT/CT contact.

2.4.2 Advances In Safety Analysis Methodology, Codes, Model Development And Understanding of Phenomena

Novel research is ongoing under the supervision of Dr. J. Luxat and D. Novog (at McMaster University) to address regulatory and operational safety of NPPs in the following areas:

- Best Estimate and Analysis Uncertainty (BEAU) methodology development for application to power uprating and margin recovery, LBLOCA power pulse and resolution of related regulatory issues
- Computational Fluid Dynamics (CFD) modeling for 2 phase flow for validation of phenomena such as that of inter-sub-channel mixing and header pressure and flow gradients
- Model Development to support SAMG (Severe Accident Management Guideline) for current plants and for design assistance in SA mitigation features in new builds

- Work in support of Extreme value statistics (EVS)applications to ROP/NOP and LOF in support of BP& OPG regulatory submissions
- Supercritical water reactor safety &T/H.

2.4.3 Advanced Research in Control and Instrumentation modeling, simulation, performance monitoring and diagnostics of relevance to the industry

Research in the following fields/applications is currently undertaken by the IRC in UWO along with his team:

- Development &validation of a newly proposed fault detection /isolation strategy for fixed In-Core Flux Detectors (ICFD) using correlations with other proximate ICFDs
- Research on the applications of wireless communication technologies to NPPs .If successful this will reduce cable runs and their installation and will reduce commissioning of plant control and instrumentation
- Advanced Shutdown Systems by applying analytically-based redundancy concepts to reduce common mode failure, improve reliability and avoid complex channel separation.

2.4.4 Understanding of Nuclear Fuel performance during normal and accident conditions including behavior of advanced and next-generation fuel designs

The SLOWPOKE -2 nuclear reactor facility at RMC is enabling fuel studies and model validation for codes such as COMSOL, Multi physics and ANSYS.

Under the IRC (Prof. Brent Lewis) supervision, ongoing PhD projects are focused on development of a defective fuel performance code, an on-line fuel failure monitoring tool and design of an instrumented out-reactor test for defective fuel studies. Two of those studies are undertaken in collaboration with AECL.

Other ongoing M.A.Sc. projects involve, amongst many ,fuel bundle modeling, fuel thermochemisty modeling for the SOURCE -2 code (in collaboration with AECL), noble gas tagging methods(in collaboration with Stern Laboratories) for demonstration irradiation, development of ultrasonic testing instrumentation for discharged CANDU bundle, stress corrosion cracking model for the ACR and a dissolution study of ACR fuel.

New research had recently been initiated on actinide burning in multispectral CANDU cores , high T fuel behavior modeling, Be-brazing reduction in fuel manufacturing (in collaboration with Cameco Fuel Manufacturing), and delayed neutron monitoring technique for defective fuel location in CANDU reactors (in collaboration with Candesco).

Other completed graduate studies projects are: gamma spectrometry analysis of coolant activity at a commercial NGS and leaching studies of Low Void Reactivity Fuel (LVRF).

The IRC program supplements R&D activities in nuclear fuel technology carried out by COG. In particular, it directly contributes to three COG work packages on fuel oxidation& behavior modeling, fuel failure monitoring and fuel thermochemistry.

The IRC research has strong collaboration with AECL (CRLand SP) on fuel studies for the ACR and with Bruce Power on gamma spectrometry, analysis of Gaseous Fission Product (GFP) and other chemistry data in support of fuel failure monitoring tools.

2.4.5 Advanced Application of Risk based Life Cycle Management (LCM)

A significant effort was made on development and integration of reliability models towards further optimization of inspection /maintenance and replacement of NPP components. These applications have begun to yield considerable benefits to the operation & maintenance of NPPs.

The IRC established at Waterloo has focused on developing probabilistic models for risk analysis to:

- Benchmark current standards and fitness-for-service methodologies and
- Solve a wide variety of tasks related to reliability of nuclear plant systems. Practical applications of this research include risk-informed LCM of Fuel Channels, steam generators, feeders and conventional electrical systems

Some of the research outcomes in the last two years had resulted in further optimization of feeder inspection and replacement at current NPPs. This has resulted in identifying 52 feeders requiring replacement (versus 110 feeders using deterministic modeling (Figure 3).

On the HTS; assessment was undertaken of the impact of increasing maintenance intervals of HTS pump seals and LRV testing.

Other applications included probability of leaks in conventional piping taking into consideration plant life and plausible degradation mechanisms.

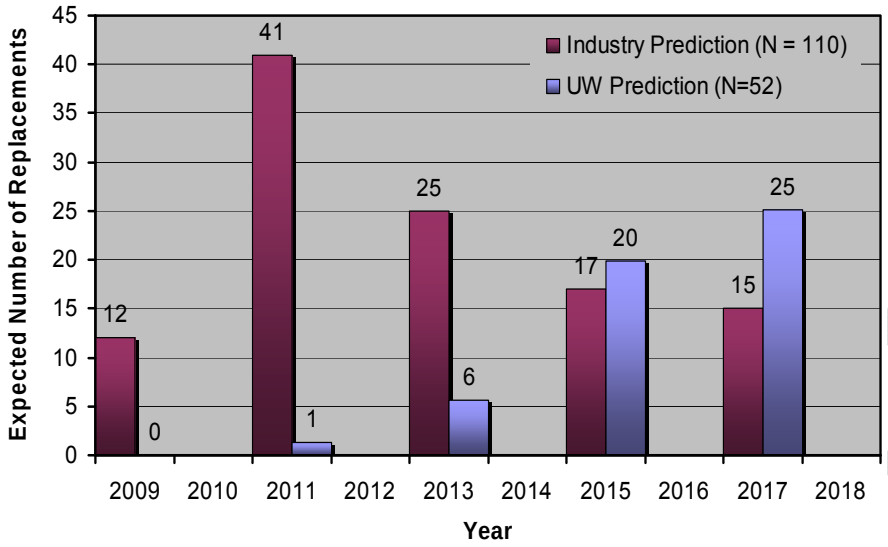


Figure 2: An application of feeder LCM model for predicting the number of feeder replacements

Other similar probabilistic based assessments were undertaken for:

- PT/CT gap analysis
- Feeder cracking susceptibility analysis
- Risk informed inspection of PT; optimum sample size
- Steam Generator Alloy 800, Lifetime Assessment and Inconel 600

Another outcome of this program is technical support to the Generation Risk Assessment (GRA) and its integration with business planning.

The GRA model was applied to assess a number of plants maintenance and refurbishment scenarios. Figure 3 shows, indicatively results of optimization of the time of refurbishment that would minimize generation risk. The unit cost in this figure refers to the unit cost of feeder replacement.

Additional details on the application of a risk based approach are in Appendices A & B by OPG and University of Waterloo IRC respectively

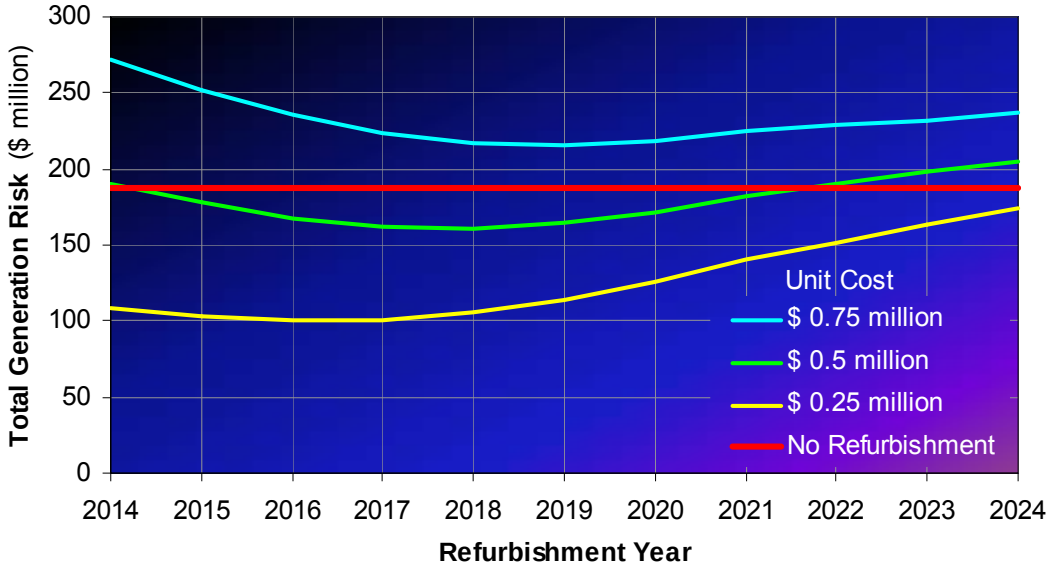


Figure 3: HTS system generation risk versus refurbishment considering feeder degradation

2.4.6 Advancing the Understanding of Corrosion and Materials Performance in Nuclear Power Systems

The current IRC`s (Professor Roger Newman at UofT) extensive experience on corrosion mechanisms in a wide range of metallic materials is providing novel and useful insights into the behaviors of nuclear materials. Such knowledge will naturally lead to an in- depth understanding of SG tubing alloys 600, 690, 800 corrosion in support of improvements in corrosion prediction and mitigation in current plants.

Alongside this theme of ongoing research, smaller projects are being conducted, such as a study of electrochemical monitoring in concrete of relevance to Spent Fuel Dry Storage Containers.

Properties and applications of nonporous metals are also being researched.

2.4.7 Improved Dose Measurement, understanding and Communication of Dosimetry and Health effects

This IRC was established on Sept 2008 at UOIT under the leadership of Dr. A. Waker (IRC) and Dr. E. Waller (associate IRC).

On April 2009, UOIT received OCGS approval for its MASc, and PhD programs in Nuclear Engineering and Health Physics enabling UOIT to fully contribute to the development of HQP.

The recently initiated research program is addressing gaps in:

- Personal alarming dosimeter for tritium-in-air for nuclear energy worker (NEW)
- Personal neutron monitoring dosimeter and detection

Both programs are aiming at a compact tritium-in-air detection system and an instrument for mixed-field neutron-gamma dosimetry in NPPs.

Another study is ongoing to address radiation weighing factor for low energy beta particles particularly Tritium in the context of CANDU reactors. This study combines methods of experimental microdosimetry and stochastic analysis which have general applicability in low dose radiation research.

Radiation Field Modeling and Mapping is another objective of this IRC program. Coupled advanced computational methods with real time measurement technology to underway to assess the use to Monte Carlo methods for mapping and visualization of radiation fields for complex geometries and work environments. The outcome of this work is envisaged to greatly enhance ALARA and work optimization in NPPs.

A significant milestone is expected in 2011 at UOIT with the completion of The Energy Research Centre Building. This centre will have laboratories specifically designed to support the IRC research including purpose-built neutron and gamma irradiation facilities. Current UOIT labs are used for detector development, aerosol research and environmental radiation.

3.0 Consultation to Industry and Government

One of the objectives of UNENE is the availability of scientific experts for independent consultation by government, public and industry. This has proven to be a valuable asset that has been extensively used by all. In the last two years over 90 consultations, technical exchanges and reviews were sought of the UNENE IRCs and Associate IRCs.

Some of the notable ones are:

- Consultation on aspects related to NRU Leak Repairs with AECL with Professors Rick Holt and Roger Newman (of Queen's and U of T)
- Instructional roles to industry professionals on topical issues of importance to industry (IRCs and associate IRCS from Waterloo, McMaster, Queen's, RMC, UOIT, UWO etc)
- Input to various provincial and federal scientific panels; for Ministry of Research and Innovation, Alberta Nuclear Power Expert Panel for advice to Minister of Energy, Government of Canada, Privy Council Office Panel April 2008 (Dr. J. Luxat of McMaster)

- Memberships in OCGS graduate scholarships for Ontario Students, Reviewers for NSERC and USDOE academic granting programs (IRC/AIRCs from McMaster)
- Authorships of Technical Textbooks or Chapters (thereof) on Control of Nuclear Reactors, Stress Corrosion Cracking ,Nuclear Fuel Chemistry etc. (IRCs from UWO, UOIT,RMC)

- Other Industry consultations such as :

    - Technical memberships of some IRCs on COG Technical Committees
    - Resolution of CNSC regulatory queries on risk based inspection, severe accident management guidelines etc.
    - Many consultations with OPG, BP, AECL on Fuel channels, feeders, fuel performance, ACR -1000 Independent Safety Review
    - Consultation to CANDESCO on Deterministic Safety analysis for NRU (AIRC at McMaster) and on Strategic Planning and recommendations on fuel/fuel channel code development (IRC at RMC)
    - Input to AMEC-NSS Defective Fuel Analysis (IRC at RMC)
    - Technical authorships/contributions to many Industry COG reports on Fuel Channel Deformation and Fuel (Queen's, RMC).

    - Joint regular seminars held between OPG NGS and UOIT (IRC) on Health Physics. UOIT also maintains an MOU with OPG to act as a backup emergency response site for environmental radiation measurements
    - Many Technical Workshops held by Waterloo IRC for OPG and CNSC on "Risk and Reliability" in support of LCM analyses and technical assessments
    - Consultation on Pickering Unit 7 CT Crack and return to service (Queen's and U of T)

4.0 Other Benefits

4.1 Integration of research programs among universities and industry

Examples of such integrations are:

- The ongoing collaboration between Queen's U, Kinetrics and AECL CRL in the F/C area
- Ongoing cooperation in the fuel cycle & physics and GenIV T/H between McMaster U and AECL-CRL
- Cooperation in fuel performance modeling and analysis behavior (RMC/CRL)

4.2 Interaction of universities with industry through UNENE Technical Advisory Committee (TAC) (AECL, BP, OPG) resulting in detailed

discussion on research directions and opportunities, ensuring industrial / university technical research objectives are met.

4.3 Publications

Advances in knowledge and technology are documented in Ph.D., M.A.Sc. theses, as well as journal publications and conference papers. This increases the profile of the Canadian nuclear technology and its depth, in support of its design and licensing basis.

Approximately 250 publications (Table 3) have been issued in the last two years, advancing knowledge in all aspects of the technology.

Table 3
Publications by the UNENE IRCs and CRDs (2007-2009)

	Safety & T/H	Control & Instrumentation	Nuclear Materials	Corrosion Of Metal Alloys	Health Physics	Nuclear Fuel	Risk Based LCM	CRDs	Total
Journal Papers		9	24	19	10	11	28	11	
Conference Papers/Presentations	∑43	11	13	10	26	6(note1)	29	14	
Total	43	20	37	29	36	17	57	25	264

Note 1: Technical COG Reports

5.0 Value of the Education Program and its Role in Knowledge Preservation/Transfer

A parallel path to training & development of HQP is the M. Eng Degree program in Nuclear Engineering, jointly offered by member universities, with strong UNENE support and overall coordination. The M. Eng program is accredited by the Ontario Council of Graduate Studies (OCGS) and is mainly aimed at industry professional for academic advancement and competency building.

Courses are given in off-working hours throughout the academic year, normally at the Whitby campus of Durham College. In 2008/2009 a Distance Learning (DL) technology was approved for use in course delivery, enabling staff at remote nuclear sites to enroll. The program uses professorial expertise residing at participating universities and draws specialist guest lecturers from UNENE Industry members. The Education Advisory

Committee (EAC) of UNENE controls curriculum matters, whereas the Program Director appointed by UNENE is responsible for enrollment, logistics, educational quality and effectiveness, instructor selection, course delivery and liaison work with universities. The UNENE Administrator executes the UNENE- and university-administrative aspects of the program.

The past two academic years experienced an increase in enrollment in the M.Eng. program, driven by the expected nuclear renaissance and the recognition given to the M.Eng. by some UNENE industrial members as a means of career advancement. As of May 2009 there was an "active" enrollment of 52, with additional applications pending. The increased enrollment enabled a commitment of a two-year cycle of all UNENE courses, with 6 offered per academic year.

Figure 4 below summarizes the cumulative throughput of students as of the same date, for the life of the UNENE M. Eng.

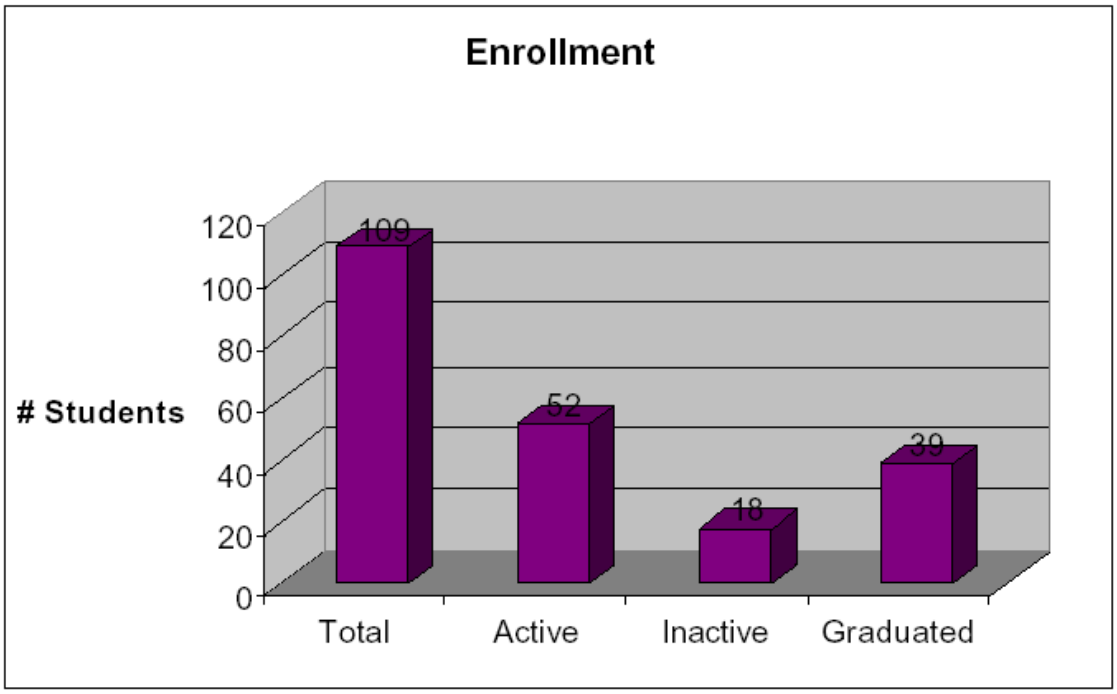


Figure 4: Student Throughput

This program offers the following benefits to industry:

- Development of HQP to meet industry needs
- Assistance to industry in knowledge transfer and preservation
- Professional / career development of employees towards an effective and highly skilled workforce
- University courses cost lower than in-house training (employees donate their time)
- Provides a forum for employee's interactions with industry and university peers

Details on enrollment by organization is shown on Figure 5 below which shows OPG students being the majority. Distant sites to date have been less active due to the lack of Distance Learning (DL) tools. Successful application of ELLUMINATE software in course deliveries since Nov 2009 is expected to increase interest from distant sites.

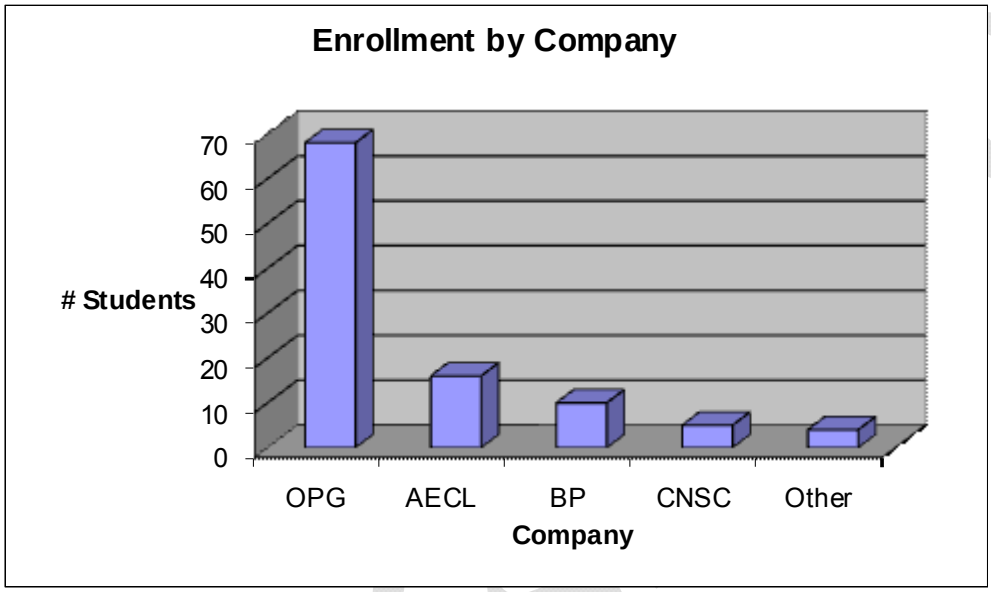


Figure 5: Enrollment by company

6.0 UNENE Funding

In the last two fiscal years the three major industry members` funding the program were OPG, BP and AECL with AMEC-NSS and the CNSC contributing each $30K/year

Table 4
UNENE Funding Details (2007-2009)

	07/08	08/09	Notes
Funding	$	$	
OPG	900K	900K	
BP	300K	300K	
AECL	300K	300K	
CNSC	30K	30K	
Cameco	-	30K	
AMEC-NSS	30K	30K	
COG (for Holt)	100K	100K	
COG (for Lewis)	94K	72K	
TOTAL Funding Expenditure	1754K	1762K	
IRCs	1.2 M	1.4 M	Covering 7 IRCs at 200k/a
CRDs	165K	165K	Covering 5.5 CRDs at 30k/a
Mgmt/Admin	192K	192K	

COG has been a funding member in UNENE, as well as additionally supporting some IRC programs through COG related Work Packages (WP). COG`s involvement and funding plays a key role in readily capturing some of the IRC research outcomes & knowledge into COG Industry reports.

7.0 Conclusion

In summary this review confirms that UNENE industry –university partnership has been a good strategic initiative and has, thus far, served all members well through successfully meeting all objectives set forth at the inception of UNENE. Research results continue to advance knowledge in all facets of the technology and support continued safety and economic performance of NPPs in Canada.
The supply of HQP has been key in addressing the demographic gaps experienced by industry in the last few years.

Acronyms

CRD: Collaborative Research and Development Project

CFI: Canadian Foundation for Innovation LCM : Life Cycle Management

GRA: Generation Risk Assessment

ICFD: In Core Flux Detectors

LBB: Leak Before Break

LCM: Life Cycle Management

OCGS: Ontario Council of Graduate Studies

USDOE: US Department of Energy

Appendix A: Major Contribution to OPGN from the UNENE/NSERC University of Waterloo- IRC

Prepared by P. Khavari (Darlington ,OPGN), pardis.khavari@opg.com

UNENE Waterloo has assisted in the "Risk-Informed Decision Making." Integration of techniques for risk and reliability analysis with Life Cycle Management Processes – LCM assisted in analyzing the condition of the major equipments such as Feeders, Fuel Channels-FC, Steam Generators-SG, Pressure Tubes-PTs, Generators, Main Output Transformers, and quantifying the effects of the aging on the generating assets. Since most plants in Canada approaching End-Of-Life-EOL, cost Effective resolution are the essential part of the decision for a successful refurbishment. Statistical analysis of the Net Present Value – NPV calculation, balances the factors between the conditions of the generating asset "Fitness for Service" with the "Asset Preservation." University of Waterloo, has developed the 'Risk-Based Life Cycle Management Model 'driven the calculation that has provided the basis for the refurbishment decisions on SGs, PTs, FCs, Feeders, Generators, MOTs, so far.
The Probabilistic Risk Assessment-PRA that is a regulatory requirement uses the Risk analysis process. UNENE at UW developed the Probabilistic Model for Risk analysis through benchmarking existing standards, and FFS methodology, and ultimately solving a wide range of practical problems related to reliability of nuclear plant SSCs. This process further developed PRA training program for the OPG-N staff.

The most significant practical research is in the following areas:

- Effective Fitness for service assessment of Primary Heat Transport-PHT components
- Effective communication with CNSC about managing risk associated with aging and degradation
- Minimizing the cost penalties associated with inspection and outage durations
- Increased operational efficiency

Development of Generation Risk Assessment-GRA to accurately assess the risk and likelihood of failure over time and optimize replacement rehabilitation cycle for major power generation assets, while meeting and exceeding the EPRI and utility standards in this process.
Conducted and updated the Seismic Risk Analysis of Structures, Systems, and Components-SSC, evaluation for maintaining Design Basis Earthquake – DBE Response Spectra calculation to meet the latest standards and regulations.
Cost saving and cost avoidance calculations for the Preventative Maintenance and Predictive Maintenance programs, to focus the maintenance activities and decide on the most cost-effective condition-based activities.

Appendix B: Impact of NSERC-UNENE Waterloo Chair to OPGN – 2009

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Introduction

This document summarizes the contributions made by the Waterloo UNENE Chair program to support the OPGN's activities related to risk and life cycle management (LCM) programs.

Research Focus Areas

- Feeders
- Valves
- Generation risk assessment
- Instrumentation tubes leakage
- Conventional systems (Transformers)
- Steam generators
- Fuel channels
- Other direct support

The Chair has carried out in-depth research and analyses of the above systems at various OPG stations. Inspection and maintenance data from OPG reactors have been analyzed for risk assessment purposes and then provided valuable input to life cycle management decisions and communications with CNSC. During the course of research and analysis, the Chair has worked with several groups, managers and engineers within OPG. We are in close contact with several groups within OPG and serve to them as a resource on a continuous basis.

Details

Number of consultation cases provided by Professor/Research expert to OPGN in support of LCM and GRA

1. Feeders: Developed a probabilistic model for life cycle management (LCM) program for feeders at Pickering A station. (180 hours)
    i. Analysis of measurement uncertainty in feeder wall thickness measurements (16 hours)
    ii. Analysis of inlet feeders wall thickness measurements (8 hours)

iii. Sample size requirement for PIP of feeder cracking investigation at DNGS. (2 hours)
iv. Probabilistic modeling of material variability (Taylor factor maps) to distinguish DNGS feeder material from PLGS cracked feeders. Extensive work has been done and Kinectrics has provided Taylor factor data. (200 hours)

2. Reliability analysis of Class 6 Relief Valves
    i. Prepared data analysis method (algorithm) for the use of OPG staff. (10 hours)
3. Generation Risk Assessment (GRA) for Darlington NGS
    i. Integration of feeder thinning model into GRA of primary heat transport system of DNGS (80 hours)
4. Instrumentation lines risk assessment (DNGS)
    i. A model has been developed for the risk-based inspection of instrumentation tube leakage (80 hours)
    ii. Application of this model to DNGS is in progress in 2010
5. Electrical Transformers: Reviewed Darlington transformers LCM plan and provided recommendations to for further data collection and analysis. (40 hours)
6. Fuel channels
    i. Developed a model for probabilistic LBB assessment that was utilized by Kinetrics for LBB assessment at OPG's stations.
    ii. Irradiation damage to fuel channels. It is a COG project and we worked with AECL to develop a probabilistic model for predicting DHC rate. (64 hours)
7. Steam Generators
    i. Developed probabilistic model for predicting the lifetime of Alloy 800 SG tubing. This is a COG project and its results are useful to Darlington NGS. (80 hrs)
    ii. The Chair is a part of COG working group on Alloy 800 testing. (16 hours, meetings, discussions)
8. Other Direct Support to OPG
    i. We have participated in several meetings with OPG staff at Pickering and Darlington locations. (96 hours)
    ii. We have numerous telephone consultations with OPG experts and COG meetings. (64 hours)
    iii. We have reviewed several notes and communications prepared by the OPG staff and provided them feedback. (56 hours)

Total number of hours: 880 hours (≈110 days) = $110,000