



CANADIAN NUCLEAR SOCIETY

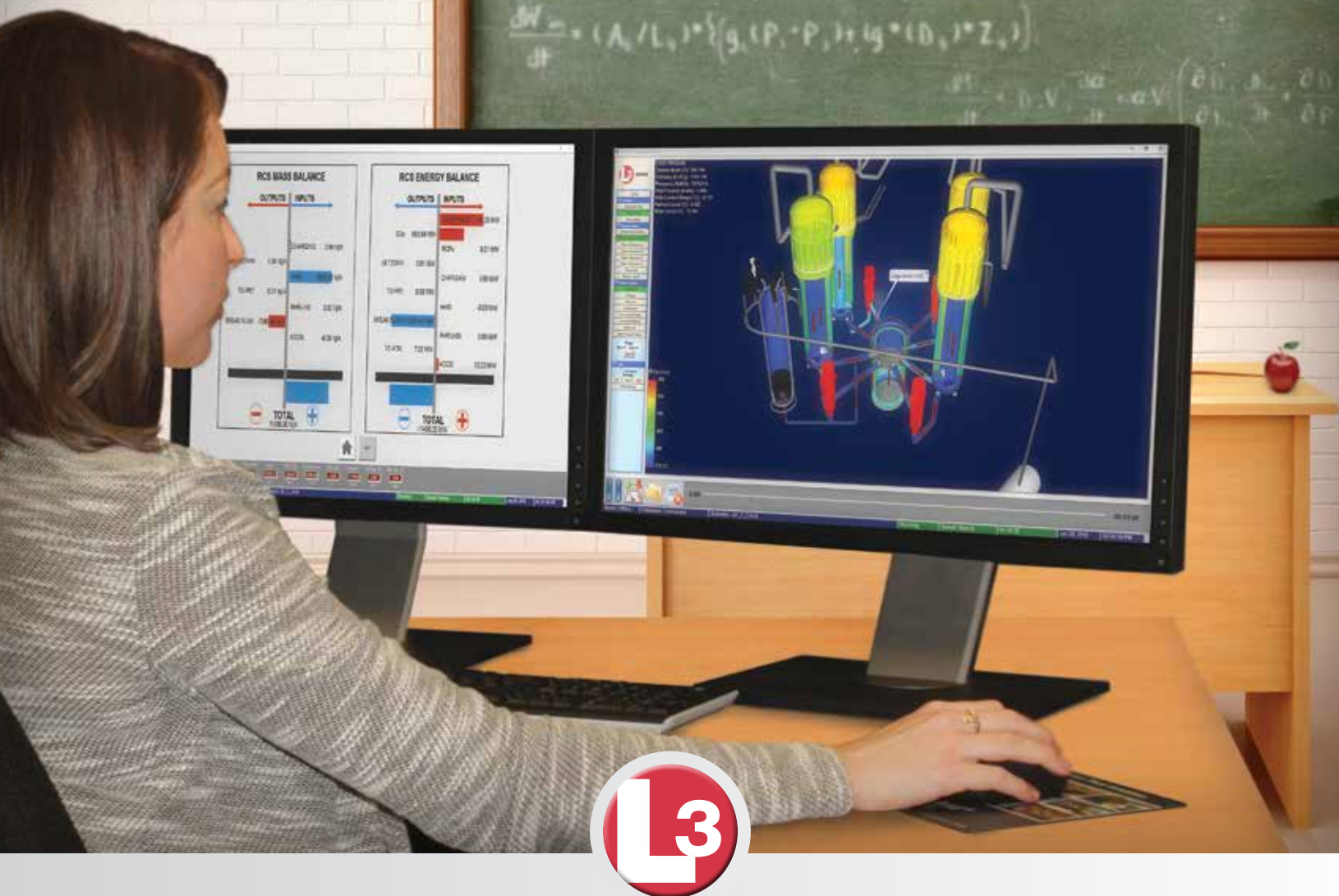
Bulletin

DE LA SOCIÉTÉ NUCLÉAIRE CANADIENNE

SEPTEMBER 2016 SEPTEMBRE VOL. 37, NO.3

- 
- 13th International Conference on CANDU Fuel
 - 3rd Canadian Conference on Nuclear Waste Management, Decommissioning and Environmental Restoration
 - 14th Congress of the International Radiation Protection Association (IRPA14)
 - New Strategic Plan for CNS

ENHANCED LEARNING FOR NUCLEAR PLANT UNDERSTANDING



Learning Simulators: Enhancing Nuclear Plant Learning

As the world's preeminent supplier of full scope operator training simulators, L-3 MAPPS introduces Learning Simulators to bridge the gap between early nuclear worker training and operator training. This innovative new software environment leverages our detailed and accurate plant models. But instead of focusing on the procedural aspects of operating your plant, Learning Simulators provides a fully interactive and visual environment designed to facilitate true understanding of your plant's behavior.

For more information on L-3 MAPPS' Learning Simulators, visit L-3com.com/MAPPS or send us a request for a white paper at power.mapps@L-3com.com.

Nuclear just got cooler!



The last two years have seen record high temperatures globally and indeed there are new predictions that the 2°C threshold, often regarded as the trigger-point for a global warming catastrophe, will be met by 2050. Like any new predictions there are sceptics but the past trend is indisputable - the world has been trending warmer. The causes of global warming are many, but the significance of burning fossil fuels cannot be ruled out. Now, more countries are taking actions since the recent Paris climate accord (COP21).

Governments are most commonly imposing a so-called “Carbon Tax”. This will make it more costly for manufacturing, home heating and anything that uses electricity. Governments woo the carbon tax for its revenue, but taxation doesn’t help the planet and it only serves to annoy people; taxation will not curtail people from doing what they need to do. To reduce emissions of CO₂, energy sources must be replaced with alternatives that do not emit greenhouse gases while allowing people to continue to do what they need to do. What are these alternatives?

Bio-fuels are touted as “carbon neutral” because the fuel is grown as a plant which absorbs CO₂ while in growth, and emits CO₂ when it’s burned. In fact bio-fuels do more harm than good to the planet. The fuel must be “grown” on a farm, consuming water and displacing food crops, and must be harvested, converted and transported to the places where the energy is needed with each process emitting more CO₂. These technologies are not carbon neutral.

Wind and solar electricity has been promoted by the Ontario Government through subsidies and higher electricity prices. Of course the wind and sun do not emit CO₂. Is that music in the hills? Not quite. Wind and solar emit CO₂ directly and indirectly; directly because gas turbines must be spinning to kick in when the wind ebbs or clouds show up, and indirectly from the manufacture of the steel and concrete needed to erect the generators. They are not effective means to combat global warming. And even though the “fuel” is free, they are costly alternatives. Indeed, the Ontario Government has cancelled

plans to expand wind and solar development to curtail hemorrhaging electricity rates.

Even hydro is not free of greenhouse gas emissions. Vast amounts of land have been flooded by dams and the old underlying vegetation decays generating methane and CO₂, as does the production of steel and concrete used in the dam. Although a better alternative than burning fossil fuels hydro sites have already largely been developed in the First World nations.

So how does nuclear fare? Nuclear electric generators are not zero emitters of CO₂, but close to it. A small amount is released when testing the diesel-fueled standby generators and during the construction of the station. But critics have claimed that large amounts of CO₂ are emitted during the mining and manufacture of the uranium fuel.

The 2014 Intergovernmental Panel on Climate Change (IPCC) has reported equivalent CO₂ emitted for various generator technologies, considering the complete life cycle of the station. It includes fuel mining and manufacturing as well as fuel consumption, station construction and waste management. Coal tops the list at 820 g-CO₂/kWh, followed by gas at 490, solar at 48 and hydro at 24. Wind and nuclear are similar at 12 g-CO₂/kWh according to the IPCC. Wind and solar, being intermittent, require back-up generation which is not considered in the IPCC report. In Ontario that backup is gas. But even the reported emissions for nuclear seem high.

A new study [see General News in this edition] examined life-cycle CO₂ emissions in everything used in mining and milling of uranium in Canada, including fuel used in heavy machinery and to power facilities, the concrete and steel used in construction, emissions from flying workers to and from the mine sites and even took into account emissions from company head offices. The result is a firm new estimate of about 1 g-CO₂/kWh, so mining contributes less than one-tenth of the IPCC estimate. Nuclear is by far the lowest emitter of CO₂ compared to any other source of electricity. It doesn’t get much “greener” than that! To combat global warming, nuclear is cool!

In This Issue

We have three conference reports in this edition covering CANDU fuel, waste management and radiation protection. CNS Member Nicholas Sion has submitted a comprehensive examination of the effects of radiation on the lens of the eye and explains why the ICRP is recommending lower dose limits. After a year of hard

work by a committee of CNS council members Past-President Jacques Plourde has submitted a new strategic direction. We also have an interesting biography to introduce our new CNS President, Peter Ozemoyah. And last but not least, Jeremy Whitlock’s Endpoint looks at the reasons to avoid new technologies.



“For Canada’s nuclear industry, the best is yet to come,” Kim Rudd, Parliamentary Secretary to the Minister of Natural Resources, proclaimed.

Ms. Rudd was speaking to the 3rd Canadian Conference on Nuclear Waste Management, Decommissioning and Environmental Restoration on September 12, 2016. She was basing her conclusion on several items: successful Canadian industry progress on managing low, intermediate and high level radioactive wastes; on the large investments committed to nuclear refurbishment in Canadian power reactors; and on the immediate prospects for new nuclear projects outside Canada.

It’s important to understand just how large a sea change has occurred over the past two decades. Bluntly, we haven’t heard positive, even enthusiastic, language like this from a federal politician in many years, possibly decades. And just to be clear, Ms. Rudd is the leading figure in the federal Liberal government charged with political responsibility for all things nuclear in Canada. Her views matter.

It all starts with the power reactors, and where the industry was and where it is now. In the mid-1990s, Canada’s nuclear sector appeared to be in domestic decline. Performance was falling across the board at all of Canada’s nuclear power stations in Ontario, New Brunswick and Quebec. The disintegration of Ontario Hydro’s Demand/Supply Plan in 1993 put paid to the prospect of new nuclear construction, a decision reconfirmed with the rejection by Dalton McGuinty’s Ontario government in 2009 with the passage of the Green Energy Act. In brief, for more than two decades, Ontario’s electricity policy was to build as much renewable capacity as possible, and to backfill any missing energy supply with gas-fired turbines.

No longer. At the end of 2015 and into the first quarter of 2016, the Ontario government made a series of agreements with Bruce Power and Ontario Power Generation (OPG) to refurbish fully all of Ontario’s operating reactors in a program lasting over a decade, involving some \$25 billion in capital and many millions of man-hours of work. Moreover, far from shutting down the six reactors at Pickering in 2020 as scheduled, the government indicated that it wanted to extend the operating life of Pickering as far as possible.

It wasn’t achieved by pretty speeches, political lobbying or favouritism or expensive fossil fuels pricing themselves out of the market. Indeed, on a constant

dollar basis, fossil fuels, particularly natural gas, have never been cheaper for Ontario.

It was achieved by performance and results. It was the work of tens of thousands of women and men in Canada’s nuclear industry through millions of man-hours of skilled, precision labour. The capstone of these two-decades of work was cemented in place this year by all three of Ontario’s nuclear sites being recognized by the Canadian Nuclear Safety Commission (CNSC) achieving the CNSC’s highest marks for safety performance. Gone are the days of lengthening outstanding maintenance backlogs and other major safety and performance issues of the mid-1990s. With 18 reactors in service, Ontario’s nuclear fleet is now producing more electricity with greater reliability and safety than it was achieving with 20 operating reactors 20 years ago.

The results of these two decades of hard work are now starting to pour in. In late September of this year, SNC-Lavalin announced its joint venture with two large Chinese companies to build the first of a new generation of CANDU reactors in China featuring advanced fuel cycles. New work for Canada’s nuclear industry will come also with agreements to proceed with Cernavoda 3 and 4 in Romania, and with a new CANDU in Argentina.

These strong results have also borne immediate fruit in Canada as well. In the last week of September, the Ontario government announced that it was canceling any new contracts for renewable energy projects in Ontario. Gone is the 20-year energy policy of nothing new except renewables and gas. And despite the current electricity supply surplus now, there will be a demand for a lot more electricity generation if the Ontario government continues with its strong promotion of electric vehicles. Regardless of whether the vehicles are battery- or fuel cell-based, the electricity will have to come from somewhere, presumably free of gaseous emissions.

That will mean nuclear generation, lots of it.

But first things first. Politicians don’t usually lead parades; they hop on the bandwagon after it’s already moving. What Ms. Rudd is really saying is that government is prepared to open a lot of policy doors. The corollary is that our nuclear industry has to continue to perform at a very high level. Recovery from the doldrums of the 1990s was only possible with a lot of very good, very hard work. And that will have to continue on a sustained basis if Canada’s nuclear industry is to retain the prestige and opportunities it’s achieved this year.

C.G.H.

Contents

Editorial.....	1
Advanced Fuel Cycles Featured at 13th International Fuel Conference	5
13th International Conference on CANDU Fuel: Summary Report on Plenary and Technical Sessions.....	8
3rd Canadian Conference on Nuclear Waste Management, Decommissioning and Environmental Restoration.....	11
Summary of IRPA14	13
L-3 MAPPS Participates in the Tihange 1 Simulator Inauguration Ceremony	16
Letters to The Editor.....	17
Seismic Fragility Analysis of a Nuclear Building based on Probabilistic Seismic Hazard Assessment and Soil-Structure Interaction Analysis	18
Dose Limits to the Eye Lens.....	25
The Travesty of Discarding Used CANDU Fuel	29

General News

SNC-Lavalin Agrees to Build New CANDU Reactors in China	36
OSART Mission Arrives at Pickering	36
Darlington Hosts World University.....	37
Low Emissions from Canadian Uranium Mining	38

CNS News

Meet the CNS President.....	40
A Modernized Strategic Direction for the CNS	42
Calendar	47
Endpoint	48

~ Cover Photo ~

Bruce Power Unit 7 Turbine is disassembled in September 2016 for planned maintenance after its record 487 days of continuous service.

Photo courtesy of Bruce Power



CANADIAN NUCLEAR SOCIETY bulletin DE LA SOCIÉTÉ NUCLÉAIRE CANADIENNE

ISSN 0714-7074

The *Bulletin of the Canadian Nuclear Society* is published four times a year by:

The Canadian Nuclear Society
c/o AMEC NSS Limited
700 University Avenue, 4th Floor
Toronto, ON M5G 1X6
Telephone (416) 977-7620
e-mail: cns-snc@on.aibn.com

Le Bulletin SNC est l'organe d'information de la Société Nucléaire Canadienne.

CNS provides Canadians interested in nuclear energy with a forum for technical discussion. For membership information, contact the CNS office, a member of the Council, or local branch executive. Membership fee for new members is \$82.40 per calendar year, \$48.41 for retirees, free to qualified students.

La SNC procure aux Canadiens intéressés à l'énergie nucléaire un forum où ils peuvent participer à des discussions de nature technique. Pour tous renseignements concernant les inscriptions, veuillez bien entrer en contact avec le bureau de la SNC, les membres du Conseil ou les responsables locaux. Les frais d'adhésion par année de calendrier pour nouveaux membres sont 82.40\$, et 48.41\$ pour retraités.

Editor / Rédacteur

Ric Fluke Tel. (416) 592-4110
e-mail: richard.fluke@amecfw.com

Publisher

Colin Hunt Tel./Fax (613) 742-8476
e-mail: colin.hunt@rogers.com

The comments and opinions in the CNS Bulletin are those of the authors or of the editor and not necessarily those of the Canadian Nuclear Society. Unsigned articles can be attributed to the editor.

Copyright, Canadian Nuclear Society, 2016

Printed by The Vincent Press Ltd., Peterborough, ON

Canada Post Publication Agreement #1722751

**Nuclear
Qualified,
Certified and
Energized**

E.S. Fox Ltd. has been in business for eighty years, designing and building major power projects throughout Canada and around the world.

As a single source of industrial construction, fabrication and engineering solutions, our integrated mechanical, electrical and civil departments ensure we adhere to, control and execute all your design requirements.

E.S. Fox Fabrication has held ASME Nuclear N, NPT, NA and NS Certifications since 2010, one of a select few Canadian Nuclear suppliers to hold these qualifications. We are also a key supplier of EPC construction and maintenance services to major nuclear power producers in the country.

For the better part of a century, E.S. Fox has achieved and continues to foster a reputation for the highest quality workmanship, engineering excellence, timely project completion and operational efficiency. We strive to be your contractor of choice.

TO LEARN MORE, CALL US AT (905) 354-3700, OR VISIT US AT ESFOX.COM



80 Years Of Integrated Construction Solutions

THESE STAMPS ARE TRADEMARKS OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS AND THE NATIONAL BOARD OF BOILER AND PRESSURE VESSEL INSPECTORS, RESPECTIVELY.



Advanced Fuel Cycles Featured at 13th International Fuel Conference on CANDU Fuel

by COLIN HUNT

Thirteen was a lucky number for this year's International Fuel Conference on CANDU Fuel, held this year on August 15-18, 2016 in Kingston, Ontario. More than 100 delegates were in attendance for this, the 13th such conference.



*Conference Chair
Dr. Paul Chan*

Conference Chair Dr. Paul Chan noted that he was very pleased with the strong turnout for the conference, and the high quality of technical papers presented. He also indicated that this conference had perhaps the strongest international representation of all of the previous fuel conferences, with representatives from 11 nations and territories in attendance.

The conference opened with an overview of CANDU research and technology, and future prospects. Mark Floyd of Canadian Nuclear Laboratories (CNL) gave the opening presentation on the current state of Chalk River Laboratories and managements' plans for renovating research facilities at the site. He reviewed the current and future research program at CNL. Of particular interest to this conference, he provided details on CNL's fuel development program. This includes both mixed oxide and thorium fuels.

Dr. Floyd came under some questioning regarding

the future of the NRU reactor at Chalk River. He indicated that CNL will indeed need irradiation services for its research program and that the company would be contracting for radiation services both within Canada and abroad.

Following Dr. Floyd was Cheryl Cottrell of SNC-Lavalin Nuclear. She outlined the developments at SNC-Lavalin with respect to advanced fuel cycles for CANDU reactors. After months of anticipation, she confirmed that the first Advanced Fuel CANDU Reactor will be built in China in a joint venture between SNC-Lavalin Nuclear and the China National Nuclear Corporation (CNNC).

Ms. Cottrell also discussed in some detail a new, strong possibility for CANDU in the United Kingdom. She noted that the UK has approximately 140 tonnes of surplus plutonium in that country's stockpiles.

"One of their preferred options is to use it in a CANDU reactor," Ms. Cottrell said.

A proposal was submitted to the UK government in 2016, with a final decision to be made on it in 2020.

A final direction in new fuel technology is the development of mixed oxide fuel in collaboration with GE Hitachi.

The third speaker, Jerry Hopwood discussed long term perspectives in using CANDU reactors for fuel recycling. He noted that, through advanced fuels, CANDU can



Conference plenary session

perform as a perfect complement to fast reactors. He observed that after 40 years of history fast reactors have not yet been demonstrated successfully on a commercial basis. He also noted that actual reprocessing of fuel is an area needing work by nuclear fuel engineers.

The opening plenary was concluded by two presentations. The first by Michel Couture provided an overview of the perspective of the Canadian Nuclear Safety Commission (CNSC) on nuclear fuel safety. The second by M. Veshchunov outlined the work of the International Atomic Energy Agency (IAEA) in nuclear fuel engineering.

Highlights of the second plenary session on the opening day of the conference included two presentations on fuel development outside Canada. The first by J.H. Park looked at developments in advanced CANDU fuel cycles in South Korea. He outlined development of the 37-pin bundle by KAERI and KEPCO, with specific reference to CANFLEX fuel. He also described the state of the DUPIC fuel program which had continued since 1991.

According to Mr. Park, the goal of the program was to increase burnup within CANDU fuel. In addition to better energy production, higher burnup would show improved safety by reducing the negative void coefficient.



*Engin Ozberk,
University of
Saskatchewan*

The morning session was concluded by featured speaker Mr. Engin Ozberk. He addressed the delegates on the importance of collaboration for research and development. In particular, he noted the advantages of collaboration between universities and industry.

The presentation by L. Alvarez looked at fuel activities in Argentina over the past three years.

The remaining two and a half days of the conference were preoccupied with parallel technical sessions. Dr. Chan noted that this

CANDU fuel conference was the most international in nature of all such conferences. He said that this was the first time the conference had drawn sponsorship from KAERI. This, and the wide variety of attendees, was an indication that considerable research and development on CANDU fuel is now being done outside Canada.

A highlight of the conference was the presentation of two Fuel Technology Awards by the CNS. The winners this year were Erl Kohn and Michael Notley.



Erl Kohn (above) and Michael Notley (below) were the winners of the CNS Fuel Technology Award. With them are (left to right) Brent Lewis, Benjamin Rouben, and Paul Chan.



Conference delegates and organizing committee (foreground)

The conference was concluded with an evening at Fort Henry hosted by the Royal Military College.

The sponsors of the conference were: AMEC-Foster Wheeler; the Canadian Nuclear Safety Commission (CNSC); the Korea Atomic Energy Research Institute

(KAERI); the Canadian Nuclear Society (CNS); NB Power; Ontario Power Generation (OPG); SNC-Lavalin Nuclear; Stern Laboratories; and the Royal Military College (RMC).



*Opening of the conference
by the Kingston Town Crier*



Venue of the 13th International CANDU Fuel Conference

13th International Conference on CANDU Fuel: Summary Report on Plenary and Technical Sessions

Submitted by HUGUES W. BONIN, Co-Chair, Technical Program Committee

[Ed. Note: This report has been edited for length.]

Plenary Sessions

The first Plenary session was co-chaired by Dr. Paul Chan (RMCC) and Dr. Mikhail Veshchunov (IAEA) with five speakers:

- Dr. Mark Floyd, *Canadian Nuclear Laboratories, "Canadian Nuclear Laboratories Fuel Science & Technology"*. He explained the context of CNL following the recent restructuring of the Chalk River Laboratories becoming a "Go-Co" (Government-owned-(Private) Company-operated) enterprise. The presentation outlined the available and future capabilities of CNL in areas such as advanced fuel development, fuel performance assessment, safety-related testing, fabrication technology and computer modelling.
- Ms. Catherine Cottrell, CANDU Energy (SNC-Lavalin), *"Key Developments in Advanced Fuel Cycles and SNC-Lavalin's Vision for the Future"*.
- Dr. Jerry Hopwood, JMH Consulting, *"Fuel Recycling in CANDU – the Global Perspective"*.
- Dr. Michel Couture, Canadian Nuclear Safety Commission, *"CANDU Fuel Safety Criteria: a CNSC Perspective"*.
- Dr. Mikhail Veshchunov, International Atomic Energy Agency, *"IAEA Activities in the Area of Nuclear Power Reactor Fuel Engineering"*.

The second plenary session was co-chaired by Dr. Hugues W. Bonin (RMCC) and Dr. Joo Hwan Park (KAERI), co-chairs of the Technical Committee. Three speakers discussed developments of CANDU fuel in South Korea, Argentina and India followed by a speaker on the causes and consequences of the Chernobyl and Fukushima accidents:

- A presentation authored by Dr. Luis Alvarez and his colleagues at CNEA in Argentina informed the audience that the Life Extension Project toward the refurbishment of the Embalse Nuclear Power Plant has begun. The main activities related to fuel engineering during this reduced utilization of the CANDU reactor centred on reducing the fuel production costs. Improvements in the storage of new and irradiated fuel were looked after, as well as better performance in the transportation of the fuel. In the time period preceding the shut-down of the reactor for its refurbishment, the fuel performance has been comparable to that of previous years, demonstrating the maturity of the nuclear system, confirming that the design and fabrication improvements

implemented then provided an increased support to the in-service performance of the fuel.

- Dr. Satish Kumar presented the last paper, written by him and his colleagues, of this plenary session, and entitled *"Resistance Welding – Preferred Technique for Appendage Welding in PHWR Fuel Manufacturing"*. Dr. Kumar described the resistance welding technique that was developed at the Nuclear Fuel Complex in India in order to improve the performance of the fuel bundles used in India's CANDU reactors and indigenous CANDU-derived PHWRs. He then covered the many testing techniques used to assess the quality of the welding technology and to ensure uniformity for the performance of the fuel. The findings demonstrate that the resistance welding has proven to be a highly reliable and successful technique for appendage welding.
- Dr. Lembit Sihver and co-authored by N. Yasuda from Austria presented their paper on the causes and consequences of the Chernobyl and Fukushima accidents. The two accidents were described and differences such as in the design of the nuclear reactors and their containments were emphasized in the light of the consequences of the accidents. The responses of the authorities of the two countries were compared, with the need of a high-level national emergency response to nuclear accidents system stressed. The presentation concluded with a discussion on the need for efficient coordination of training of rescue workers and first respondents, plus a strong education program for the general population.

Technical (Parallel) Sessions

Session 1 *"Performance, Reliability & Operational Experience"*, was in two parts. The first part was co-chaired by Dr. Brent J. Lewis, Professor Emeritus, Royal Military College of Canada, and Dr. John Beale from Electric Power Research Institute (EPRI) in the United States. The second part was co-chaired by Dr. Paul Gillespie from AMEC Foster Wheeler) and Dr. Gord Hadaller from Stern Laboratories.

- Dr. Keith Ellison, *"Microscopic Examination of Unirradiated CANDU Fuel from Darlington Nuclear GS"*.
- John Armstrong et al., *"Post-Irradiation Examination of Bruce NGS Elements at CNL"*.
- Dr. Brent Lewis et al., *"Application of the WANO Fuel Reliability Indicator for PHWRs"*.
- *"CANDU Advanced Fuel Technology Development in*

China – Perspective, Roadmap and Status”.

- “*Establishing and Sustaining a Technical Program to Achieve Zero Fuel Failures*”.
- P. Gillespie *et al.*, “*Axial Load Limits on CANDU Fuel*”
- P. Gillespie *et al.*, “*Fuel Bundle Passage in Aged Fuel Channels*”.

Session 2 “*Special Topics*”, was also in two parts. The first was chaired by Dr. Alexandre Viktorov (CNSC), and the second by co-chairs Dr. Luis Alvarez (CNEA) and Dr. A. Pradhan (NPCIL).

- Dr. J.G. Roberts (JGRchem. Inc.) “*How to Minimize Fuel Failure (and other Surprises) Following Either Reactor New Build or Refurbishment*”.
- M. El-Hawary of CNSC, “*New Contact Boiling Experiments to Evaluate Calandria Tube Strain Acceptance Criteria*”.
- “*Analysis of Pressure Tube Measured Data for CANDU Reactors*” by J.Y. Jung *et al.* (KAERI).
- “*Application of Guided Wave Technology for Detecting Defects in Fuel Rods*” by J. Beale *et al.* (EPRI),
- “*Spark Plasma Sintering of Uranium Nitride Fuels*” by J. Wallenius *et al.* (KTH Royal Institute of Technology (Sweden)),
- “*Romanian Experimental Research on Fuel Performance*” by G. Olteanu *et al.* (INR Romania).

Session 3, “*Advanced Fuel Cycles – Thoria and 60Co Production*” was co-chaired by Jerry Hopwood (JMH Consultants) and Janne Wallenius (KTH).

- “*Progress in the Development of Thoria Fuel Science & Technology*” by Mark Floyd *et al.* (CNL),
- “*Thorium Based Fuel Performance Modelling and the Development of Multi-Pellet Material Fuel and Sheath Modelling Tool*” by Stuart Bell and Paul Chan (RMCC),
- “*First Principles Study of Thermal Conductivity of Nuclear Fuel Materials*” by B. Szpunar *et al.* (Univ. Saskatchewan), and
- “*Neutronic Analysis of an In-Core Co-60 Production in a CANDU 6 Reactor*” by L. Jinqi *et al.* (KAIST).

Session 4, “*Advanced Fuel Cycles – MOX*”, was co-chaired by Mark Floyd (CNL) and Fabricia Pineiro (SNC-Lavalin).

- Two papers were presented by SNC-Lavalin, and two by Canadian Nuclear Laboratories (CNL). The first SNC paper focused on the unique contribution of CANDU technology in the battle against climate change, and was presented by Fabricia Pineiro. The Advanced Fuel CANDU Reactor (AFCR) is designed to operate with DRU and LEU/thoria fuels and is approaching deployment in China. The CANMOX EC6 reactor is capable of burning MOX fuel and is under consideration for dispositioning Pu in the United Kingdom.
- The second SNC paper described an initiative to extend the ELESTRES fuel performance code for use with MOX fuel and was presented by Girma Chassie.

- The first CNL paper described the post-irradiation examination of two 37-element geometry MOX bundles. Overall, the performance of both bundles was similar to that expected on UO₂ fuel.
- The second CNL paper described preliminary results of modelling MOX fuel using the MOOSE-BISON platform (Idaho National Laboratory) and was presented by Andrew Prudil. The modelling results were compared to post-irradiation measurements made on PARALLEX MOX fuel irradiated in the NRU reactor (fuel made from weapons-surplus plutonium).

Session 5, “*Design and Development – I*” was co-chaired by Raheel Hameed (Cameco) and Dr. Andrew Prudil (CNL).

- “*Optimal Neutron Absorber Location to Mitigate End Flux Peaking in CANDU Fuel Bundles*” and was authored by D. Pierce, P. Chan and W. Shen (RMCC).
- “*The modification of Fuelling Frequency and the Use of Bundle Absorber in CANDU Reactors*” was presented by Christy Bruce from RMC.
- Mohammad Abdul Motalab from Korea Advance Institute of Science and Technology (KAIST), “*Erbia-Loaded CANDU Fuel for Minimization of the Coolant Void Reactivity*”

Session 6, “*Design and Development – II*”, was chaired by Dr. Rick Fortman (Stern Lab).

- “*Repeatability of Full Scale 37 M Critical Heat Flux Experiments Performed at Stern Laboratories*” by Rick Fortman *et al.*,
- “*Mechanical Behaviour of High Burnup PHWR Clads*”, by J. Dubey *et al.* (Bhabha Atomic Research Centre, India), and
- “*Fretting Corrosion of Zirconium Alloys*” by M. Wash (MRW Consulting).

Session 7, “*Modelling & Computer Development – Fuel Performance*” was co-chaired for its first half by Wenzhong Zhou (City University of Hong Kong) and Kang Moon (KNFC) and, for its second half, by Dr. Diane Wowk (RMCC).

- “*Modelling of Fuel Bundles Deformation under High Temperature Transient Conditions*” by Z. Xu *et al.*, (CANDU Energy),
- “*CAMPUS: A Fully Coupled Multiphysics Modeling Approach for Light Water Fuel Performance*” by R. Liu *et al.* (City University of Hong Kong and RMCC),
- “*3D Modelling Capability for CANDU Fuel Performance*”, by G. Chassie & M. Shams (CANDU Energy), and
- “*Applicability of Evaluation Models in the PWR Fuel Performance Code ROPER for CANDU Fuel*”, by J.S. Ji *et al.* (KNFC).
- “*The Other Metallic Phase in Spent Nuclear Fuel: A Complete Thermodynamic Evaluation of the U-Pd-Rh-Ru System*”, was presented by Dr. Matthew Kaye (OUIT).

- “*Thermodynamic Considerations in the Use of Inconel to Braze Zircaloy-4*” by Sheldon White (RMCC).
- “*A Method for Predicting the Evolution of Crack Growth in Complex Structures – A Potential Application in Simulating Stress Corrosion Cracking*”, was presented by the session Chair, Dr. Diane Wowk (RMCC).
- “*Status of the Development of SOURCE IST 2.0*” by Paul Gillespie from AMEC Foster Wheeler.

Session 8, “*Spent Fuel Bay Operation*”, was co-chaired by Dr. Wade Grant (CNSC) and Richard Scrannage (Bruce Power).

- “*Predicting the Behaviour of Defected CANDU Fuel Oxidation in Air with the USA DOE Semi-Empirical Model for the Oxidation of Defected LWR Fuel*”, by J. Freire-Canosa (Nuclear Waste Management Organization (Canada)).
- “*CNSC – IFB Loss of Cooling Severe Accident Work*” and was presented by Dr. Wade Grant, the co-chair of this session.

- “*CANDU Fuel Defect Bundle Transfer Platform*”, was presented by R. Kozeluh (Pickering NGS).

Session 9, “*Modelling & Computer Code Development – Aging and Deformation*”, and was co-chaired by Drs. Markus Piro (CNL) and Jong Yeob Jung (KAERI).

- Dr. J.Y. Jung *et al.* (KAERI) and entitled “*Modeling of the CANDU Pressure Tube Diameter Expansion*”.
- “*Analyzing Fuel Bundle Deformation Using the Finite Element Method*” by R. Soni *et al.* (RMCC) was presented by SLt. Soni.
- “*Finite Element Simulations of a Fuel Element Simulator Sagging Experiment*” by A. Williams *et al.* (CNL), was presented by Dr. A. Prudil.

- M. Piro *et al.* (CNL), “*Investigation of Fluid Flow within a 37-Element CANDU Fuel Bundle in a Normal and Deformed Pressure Tube*”.

Session 10, “*Fuel Fabrication and Code Design*” was co-chaired by Thomas Onderwater (GE-H) and Steve Goodchild (OPG).

- “*Automated Inspection Systems for PHWR Fuel at Nuclear Fuel Complex*” by C. Phani Babu *et al.* (Nuclear Fuel Complex, India),
- “*Vision Based Smart Systems for Reliable Nuclear Fuel Pin Manufacturing*” by N.V. Satish Kumar *et al.* (NFC India),
- “*Characterization of Zr-2.5Nb-0.5Cu Garter Spring with Corrugated Girdle Wire Design for 700 MWE PHWRs*” by R.K. Chaube *et al.* (NFC India), and
- “*Burning Plutonium in the Multi-Spectrum CANDU-Based Reactor (MSCR) Using the SERPENT Code*” by M. Hussein *et al.* (RMCC).

Sessions 11 to 14 were all entitled “*Fuel & Fuel Channel Safety – Thermalhydraulics*”. Session 11 was co-chaired by Dr. Se-Myong Chang (KNU) and Dr. Magdy El-Hawary (CNSC).

- Dr. Chang, “*Multiphysical Unsteady Simulations of Ballooning PT and CT Contact in the Benchmark Model of IAEA/ISCP*”.
- “*CNSC Perspective on CANDU Fuel Thermalhydraulic Design*” was authored and presented by Dr. Yujun Guo (CNSC).

- A. Tahir and A. Popesco (AMEC-Foster Wheeler), “*Role of Circumferential Wall Conductance on Post Dryout Temperature*”.

Session 12 was co-chaired by Dr. David Law (New Brunswick Power) and Dr. E. Corcoran (RMCC) and was entitled “*Modelling & Computer Code Development – Advanced Methodology*”.

- “*Two-Phase Flow CFD Simulations of a 37-element CANDU Fuel Channel under Onset of Significant Void (OSV) Conditions*” by F. Abbasian *et al.* (Stern Laboratories),
- “*UMoO₆ Preparation for the Study of Nuclear Fuel Oxidation*” by R.A. Barry *et al.* (RMCC),
- “*Multi-Physics Reactor Transient Simulations through a SALOME-Backbone Joint Platform*” by Y. Liu *et al.* (CNL), and
- “*Improved Annular Flow Dryout Model in the Subchannel Code ASSERT*” by M. Shawkat *et al.* (AMEC Foster Wheeler).

Session 13, “*Safety and Operational Margin Improvement – AOO*” was co-chaired by Dr. Michel Couture (CNSC) and Dr. Shen Fan (TQNPC).

- “*Determination of the Threshold Conditions for Delayed Hydride Cracking in Zircaloy-4 CANDU Fuel Cladding – AECL’s Contribution to IAEA CRP*” delivered by Zhang He from the Canadian Nuclear Laboratories.
- “*Failed Fuel Location by Xe-133 Trend in CANDU6*” delivered by Wei Hu from CNNP Nuclear Power Operation Management Co., China
- “*Fuel Defect Detection and Location Methods at PNGS*” delivered by Kat Vizmuller from Ontario Power Generation.

Session 14, “*Safety Operational Margin Improvement – LOCA*” was co-chaired by Dr. Emanoil Relu Istrate (Cernavoda NPP, Argentina) and Masoud Shams (SNC-Lavalin).

- E.R. Istrate from Cernavoda NPP, “*Fuel Behaviour after a LOCA Followed by a Site Design Earthquake at 24 Hours after the Initial Event*”.
- “*High-Temperature Bundle Deformation Experiments under Conditions Applicable to LBLOCA with ECI Available*”, was presented by F. Abbasian from Stern Laboratories
- “*The Effect of the Molten Corium Temperature on the Predicted Melt Penetration Distance*”, was presented by J. Tang from VRS Ltd.
- H.Z. Fan from SNC Lavalin, “*Assessment of Fuel and Fuel Channel Behaviour at High Temperature during a Postulated LOCA/LOECC Event*”.

3rd Canadian Conference on Nuclear Waste Management, Decommissioning and Environmental Restoration

Canada's industry leading the way in successful waste management

by COLIN HUNT

"The best is yet to come for the nuclear industry," Parliamentary Secretary to the Ministry of Natural Resources Kim Rudd told the 3rd Canadian Conference on Nuclear Waste Management, Decommissioning and Environmental Restoration.

Speaking to conference delegates in Ottawa on September 12, 2016, Ms. Rudd stated that three main factors showed great promise for future growth of Canada's nuclear industry. The first was the Paris Summit of 2015 in which world leaders agreed to limit carbon dioxide emission. That, according to Ms. Rudd means a great need for large amounts of clean power. In support of this goal, Canada, the United States and Mexico agreed that 50 per cent of these nations' electricity must come from clean power.

That means lots of nuclear, according to Ms. Rudd. She noted that Canadian utilities have already begun to do their part with the agreements for refurbishment of the Bruce and Darlington nuclear generating stations. These refurbishments will mean that the majority of Ontario's electricity will continue to come from nuclear power past the midpoint of this century.

"It's already started," Ms. Rudd stated in her speech. "Ontario's multi-billion dollar investment in nuclear refurbishments of the Bruce and Darlington Nuclear Stations ensures that nuclear will be an important part of Canada's energy mix for decades to come."

The global awakening provides "the opportunity for Canada to lead the transition to a lower-carbon economy," Ms. Rudd said.

For Ms. Rudd, there are two other strong indicators of a great future for Canada's nuclear industry. The first is the drive for new nuclear technology.

"Candu Energy is a perfect example. Its Advanced Fuel CANDU Reactor represents a novel approach for re-using fuel from light-water reactors. It represents



Kim Rudd, Parliamentary Secretary for Natural Resources, with Peter Ozemoyah, CNS President



Conference Host Ken Nash, President and CEO, NWMO

a major export opportunity for both CANDU and Canada's entire nuclear supply chain.

"The timing couldn't be better," she continued because China is the "largest world market for nuclear energy technology" with 24 new power plants to be in operation by 2040.

The second key indicator was the strides Canada was making in the successful management of radioactive wastes, both low level and high level used fuel. She credited the Nuclear Waste Management Organization (NWMO) for its work in developing and gaining government approval for

its long term plan, and for its work with nine communities interested in hosting a long term waste management facility. Ms. Rudd also referred to the development of the low and intermediate waste facility at the Bruce site, and to the agreement this year for the final cleanup and disposal of low level material in Port Hope, Ontario.

The Conference, September 11-14, 2016, commenced on Monday, September 12, with opening remarks by Conference Host Ken Nash, President and CEO of the NWMO. He characterized the nuclear industry as being unique for its responsibility for managing its complete nuclear fuel cycle. He noted that at this time, Canada has three distinct repository projects at various stages of approval or implementation: clean-up of sites around Port Hope, Ontario; environmental approval of the low and intermediate facility at the Bruce site; and the

NWMO's main project of working with volunteer host communities for a final repository for used nuclear fuel.

"Canada has an opportunity to show leadership on how to accommodate the views of different communities within our country," Mr. Nash said.

Mr. Nash said he was very pleased with the strong

attendance and support at this year's conference. This 3rd Canadian Conference on nuclear waste management was supported by 340 delegates from 10 nations and 40 organizations.

Mr. Nash was followed by Laurie Swami, Honorary Conference Chair and Ontario Power Generation (OPG) Senior Vice President, Decommissioning and Nuclear Waste Management.

"Nuclear waste is an industry strength, not an Achilles Heel," Ms. Swami prefaced her remarks. She noted that Canada's nuclear industry has successfully managed all of its radioactive wastes for more than 45 years.

She observed that in 2012, industry leaders recognized that a national strategy was required for comprehensive management of radioactive wastes. This resulted in the formation of the Nuclear Leadership Forum with five member corporations and a 25-year vision for all Canadian wastes. She indicated that the plan had been slowed somewhat by the breakup and sale of the research and reactor divisions of Atomic Energy of Canada Limited (AECL), but that the NLF was continuing its work and would be holding increased stakeholder consultations in 2017.

The first plenary session of the conference continued the themes introduced by the opening speakers. Derek Wilson, Vice President NWMO outlined the current draft configuration of a proposed repository for used nuclear fuel. He showed how the current version offered enhanced security and reduced costs compared to the original concept. He also noted that the work of the NWMO had been helped considerably by their cooperation with NAGRA, the waste management organization of the government of Switzerland.

Following him was Craig Hebert, General Manager of the Port Hope Area Initiative. Mr. Hebert noted that PHAI had been active since 2001. Relocation to secure facilities of Port Hope radioactive wastes would start in October of this year, commencing with material at the Port Granby site.

Speaking next was Gord Sullivan of OPG. He discussed developments in 2016 regarding the Deep Geologic Repository (DGR) at the Bruce site for low and intermediate wastes. The Minister of Environment Canada requested additional information last year prior to considering approval of the project after it had received a positive recommendation from its environmental assessment review panel. Mr. Sullivan indicated that all information requested will be submitted



Honorary Conference Chair, Laurie Swami, Senior Vice President, OPG

in December 2016. This will include consideration of two other locations for the facility.

Two very interesting presentations that morning came from Lise Morton of OPG and Tim Dalpee of Bruce Power. Ms. Morton discussed OPG's pilot project in sorting materials contaminated by low level radioactivity. Of critical importance was reducing the amount of metal that went to waste streams to reduce the overall tonnage of wastes. Once metals were removed from wastes by washing, the pilot program had shown a reduction of waste volumes by a 5:1 ratio by improved sorting and processing techniques.

Tim Dalpee illustrated a similar story in actual waste reduction. Through improved sorting and preparation, Bruce Power had reduced its low level waste stream from 27,000 bags annually to 21,000 bags.

Such a large conference attracted strong support from both delegates and organizations. The principal sponsors included: Host Sponsor: NWMO; and Sponsors: Bruce Power; Canadian Nuclear Laboratories; the Canadian Nuclear Safety Commission (CNSC); Kinectrics; Hardy, Stevenson and Associates; New Brunswick Power; Nuvia Canada; Ontario Power Generation; Rolls Royce; and Terraprobe.



The Organizing Committee [L-R]: Mohinder Grover (Treasurer); Pauline Watson (Plenary Program Chair); Laurie Swami (Honorary Conference Chair); Parva Alavi (Organizing Committee Chair); Peter Ozemoyah (Publicity/Media Chair); Ruth Burany and Julia Dinner (Event Co-Chairs); Jennifer Noronha (Technical Committee Chair); and Ben Rouben (Venue Chair). Missing are Conference Host Ken Nash, Sponsorship Chair Marie Wilson and Registration Chair Bob O'Sullivan.

Summary of IRPA14

“Practising Radiation Protection: Sharing the Experience and New Challenges”

by NICK SION



Fig. 1 Opening ceremony



Fig. 2 The Convention Centre

The International Radiation Protection Association held its 14th congress [IRPA14] in Cape Town May 9-13, 2016 with a strong emphasis on the effective practice of Radiation Protection [RP].

After a full day's business meeting, the opening ceremony was ushered by a fanfare of trumpets. The attendees numbered over 900 and came from 72 countries. Four new associations joined IRPA viz. Cameroon Radiological Society; Tunisian Radiation

Protection Society; Ghana Association for Radiation Protection; and the Nigerian Society for Radiation Protection making a total of 67 associations with IRPA. The IRPA membership is about 18000 members.

The IRPA Bulletin is now published in Chinese, Arabic, Spanish, Japanese and in English too ! To disseminate the Radiation Protection [RP] culture there was the urge to distribute the Bulletin to the membership in print form and also via social media, i.e. making it truly international. This endeavour is aimed to produce world-wide consultations, achieve Guidelines via collaboration; and incorporate the approaches made in different countries.

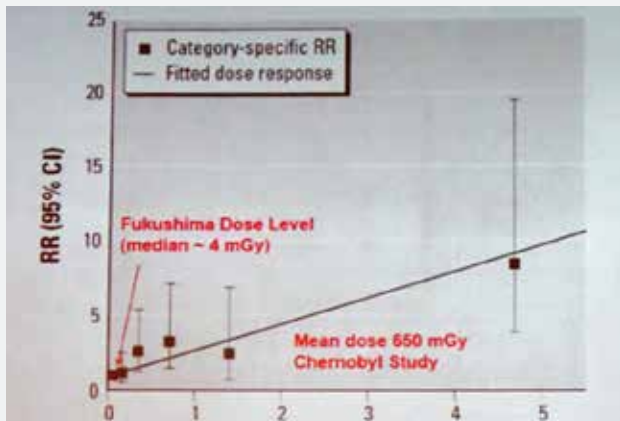


Fig. 3 Ukrainian-American Thyroid Study after Chernobyl accident *Keynote Lecture: John Boyce*

South Africa [S.A.] is embarking on an ambitious nuclear program with the intent to produce 9600 MW_e from nuclear by 2030. New legislation will address

Table 1 Cancer Risks From Alpha Emitters

Radon	Lung cancer
Thorotrast [ThO ₂]	Liver cancer and Leukaemia
Radium isotopes	Bone cancer
Plutonium-239	Lung, Liver and Bone cancer

*Source: Harrison and Muirhead, 2003 J. Rad'n Biol. 79 1-13
Little et al 2007, Rad'n Environ. Biophys. 46 290-310*

Table 2 Cumulative Dose of Polonium-210, in Gy, With Time After Ingestion

Time after intake, days	RBM *	Gut	Liver	Kidneys	Skin
1	0.8	0.2	5.0	8.1	0.6
5	4.5	1.1	28	44	3.6
10	8.7	2.0	51	80	7.9
15	12	2.8	70	110	13
20	16	3.5	86	130	18

* Reduced basis method See Footnote to Table 2
Source: John Harrison; ICRP Committee #2

the fears of the general public from nuclear energy. The S.A. Dept. of Energy will soon start procurement for the new builds and implement the IAEA Safety Programs to ensure public confidence Ref. 1. Nuclear medicine is widely accepted by the S.A. public. Young professionals are encouraged to inform and educate the general public re: nuclear energy.

Dr. John Boyce gave the Sievert lecture and spoke at length on the radiation effects towards leukemia, breast and cervical cancer that seem to affect the younger women [<40 years], and on fluoroscopy. After the Chernobyl accident thyroid cancer was an “epidemic” in children who drank contaminated milk. In

Footnote to Table 2

1. Reduced Basis Method: Is a simulation of data with large information content and computational complexity to reach a certain level of accuracy by considering representative snap-shots.

the Ukraine, I-131 levels reached 650 mGy, Fig. 3 and again the younger women were susceptible.

It was noted that Radon in houses had a dose of 40 Bq/m³ and there is evidence that smoking plus radon enhances the cancer risk.

Cancer risks from alpha emitters are shown in Table 1. The Thorotrast is a suspension of radioactive particles of Thorium Dioxide [ThO₂] that was used in medical radiography a few decades ago. However the Thorium is retained in the body and emits alpha radiation as it decays, this has shown an increase risk in certain cancers such as angiosarcomas and angiosarcomas of the liver. But on a more potent scale, Polonium has proved deadly, as in the case of Alexander Litvinenko, in London 2006, where his ingestion of 210Po is estimated to have been 4 GBq. (100 mCi equivalent to 20 µg of 210Po). The 50% lethal dose [LD50] is around 238 µCi or 50 nanog, if ingested. The effects are shown in Table 2. Apart from the acute effects Polonium has a long term risk of death from cancer of 5-10% per Sv due to Radon daughters. Also noted that tobacco smoking causes additional exposure to polonium.

Polonium is extremely toxic, about 5 million times more than hydrogen cyanide.

A plausible and practical judgment on Low Dose Radiation and the Linear Non Threshold Hypothesis was discussed and the outcome was inconclusive. The risk below 100 mSv is still uncertain, hence there is a need to reconsider the LNT. Quotes from different sources are shown below:

NCRP 136 states “*No conclusive evidence to reject the assumption*”. This maybe true or not!!

ICRP 103(66): “...whilst the LNT model remains a scientifically plausible element in its practical system of radiological protection, biological/ epidemiological information that would “*unambiguously verify the hypothesis that underpins the model is unlikely*” to be forthcoming”.

NCRP SC 1-25: “... continuously being assessed”!!

CERN [Conseil Européenne pour la Recherche Nucléaire] is the largest particle physics laboratory in the world and provides accelerators for high energy



Fig. 4 CERN Hadron Collider

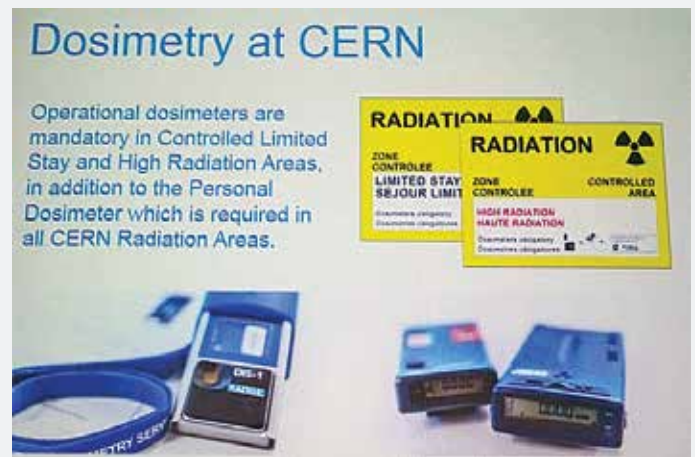


Fig. 5 Dosimetry at CERN Hadron Collider

physics Fig. 4. It comprises two Linacs, a Proton Synchrotron Booster; a Low Energy Ion Ring to transfer ions to a Proton Synchrotron; a Super Proton Synchrotron; and an Antiproton Decelerator; 45 km of tunnels with 52 access points And employs 9000 radiation workers.

Dosimetry at CERN Fig.5, involves two types of dosimeters, Level 1 and Level 2 each with different roles and ranges.

Level 1 is for α , β , γ , n radiation with a range of up to 0.5 mSv.

Level 2 is for particle radiation with a range of up to 5 mSv.

Collective doses have been reduced to 0.5 mSv/y.

Recommendations on Emergency Preparedness after the Fukushima disaster are:

- a) Leave the assembly area: When the dose rate reaches 10 µSv/h.
- b) Site Evacuation: when the dose rate reaches 100 µSv/h, issue Iodine pills, breathing masks, have dose and dose-rate alarms available.
- c) Radiation Protection personnel are to act as **Advisors** and not as **Deciders**.
- d) Transparency with the public.

It is interesting to note that nobody had died from radiation as a result of the Fukushima accident!

The lessons learned from the Fukushima event, and with considerable hindsight, are:

- Common cause failure made it difficult to control abnormal operations to within the Design Basis.
- The measures to prevent the progression of events beyond Design Basis were not enough.

Current remedial action taken are:

- A Filtered Venting System with silver zeolite filters has been developed for iodine capture, and is being installed.
- Multi-nuclide aerosol filters for radiation protection

during cutting and removal of core debris are developed at Hokkaido University.

- Nuclear education is instituted to improve public awareness and safety culture.

Further system enhancements would include tsunami waterproof doors, mobile water pumps, plasma and laser cutters, and drilling machines for the debris.

These extra remedial enhancements resulted in the restart of Sendai 1 and Sendai 2 nuclear power plants. Several other PWRs will also restart; and Kashiwazaki-Kariwa (ABWR) are due to pass the restart tests in 2016.

The Chernobyl 1986 accident caused 28 deaths and 134 people were exposed to acute radiation levels. Emissions were $\sim 14 \times 10^{18} \text{Bq}$ of which $1.8 \times 10^{18} \text{Bq}$ were due to I-131. Exposure to ^{137}Cs is shown in Fig.6 [Richard Wakefield, Univ. of Manchester]. Thyroid dose to children were $>1\text{Gy}$.

Risk estimate studies following Chernobyl contamination are broadly compatible with predictions from external studies. There is also evidence for a modifying effect of iodine at the time of exposure (which increases risk), and of stable iodine supplementation after exposure (decreases risk). Other uncertainties are the effects of the short-lived isotopes of iodine e.g. ^{133}I in screening for thyroid disease.

The current hot topic is radiation dose to the lens of the eye that may induce cataracts where radiation monitoring is not straightforward and is often not done at all. Specialized dosimetry is needed. Further discussion on this subject by the author follows as a separate article.

The next IRPA meetings have been scheduled at: IRPA15 in 2020 at COEX [Convention & Exhibition Centre] hosted by KARP [Korean Association for Radiation Protection]

IRPA16 in 2024 in Orlando, Fl. And will be hosted by Health Physics Society, USA.

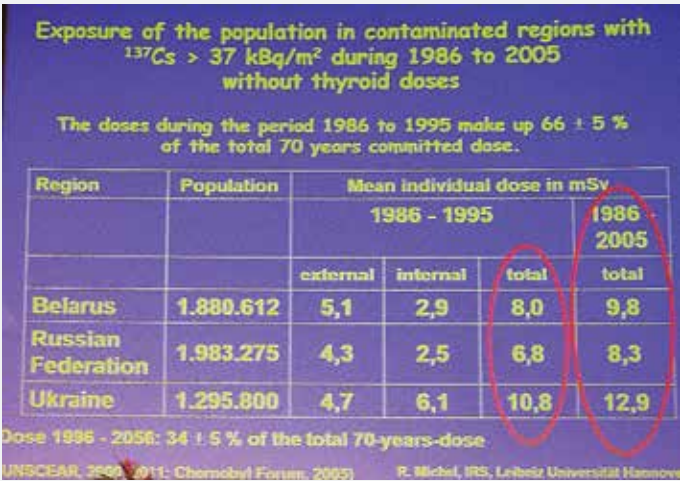


Fig. 6 Cs-137 Contamination in Three Affected Countries Rolf Michel, Leibnitz University, Hannover

References

Ref. 1 Keynote address by Mr. Zizamele Mbambo on behalf of the Minister of Energy Ms. Tina Joemat-Pettersson, MP; and Mr. Thabo Tselane President of South African Radiation Protection Association (SARPA).

Radiation Hardened Accelerometers Operating to +399°C

The model 2273A series is a family of radiation hardened piezoelectric accelerometers for vibration measurements within nuclear and power generation environments.



- » High sensitivity of 10 pC/g
- » Top (model 2273AM20) and side connector (model 2273AM1) versions
- » Radiation hardened for exposures to gamma flux up to 6.2×10^{10} and integrated neutron flux up to $3.7 \times 10^{18} \text{N/cm}^2$
- » Temperature range -184°C to +399°C (-300°F to +750°F)
- » Reliable operation at frequencies of up to 6000 Hz



**HOSKIN
SCIENTIFIC**

www.hoskin.ca

Vancouver | Burlington | Montréal

604-872-7894 905-333-5510 514-735-5267

**Endevco
MEGGITT**

L-3 MAPPS Participates in the Tihange 1 Simulator Inauguration Ceremony in Belgium

MONTREAL, September 21, 2016 – L-3 MAPPS announced today that it participated in the official inauguration ceremony of ENGIE Electrabel’s (Electrabel) Tihange 1 full scope operator training simulator on September 21, 2016. The new simulator, declared Ready For Training on March 4, 2016, is housed in the expanded training center located at the Tihange nuclear power plant in Huy, Belgium. The inauguration ceremony was attended by numerous Electrabel and ENGIE Tractebel representatives. L-3 MAPPS’ team was led by Vincent Gagnon, sales manager of Power Systems and Simulation.

“Electrabel is very impressed with the state-of-the-art Orchid®-based Tihange 1 full scope simulator,” said Jean Brogneux, Tihange simulator training manager. “The project success is the result of the L-3 MAPPS team’s focus, dedication and commitment to a quality simulator. The atmosphere of collaboration and trust developed over the course of the project between Electrabel and L-3 is a key factor to the simulator being delivered on schedule and on budget.”

“This project is a fine example of excellent large-scale simulator project management and execution in which the stakeholders all worked in an open environment to address challenges head-on and keep the project advancing while never compromising quality,” said Michael Chatlani, L-3 MAPPS’ vice president of marketing & sales. “We would like to thank all the contributors that made this effort a great success, including Electrabel, Tractebel, the L-3 MAPPS project team and our main subcontractors, ENGIE Fabricom and Macq Traffic & Automation.”

The Tihange 1 full scope simulator, equipped with full replica control room panels, is based on L-3’s state-of-the-art graphical simulation PC/Windows-based tools for the plant models and instructor station. Most plant systems are simulated in the Orchid simulation environment, including the reactor, nuclear steam supply systems, balance of plant systems, the electrical AC and DC distribution systems, and I&C systems. The electrical grid, including the main generators and transformers, is modeled with FAST, a product of Tractebel.

Electrabel is one of Europe’s front-runners in the energy sector and the Benelux market leader and is active in the production of electricity, the sale of electricity, gas and energy-related services and energy trading. Electrabel is part of ENGIE Group, an international industrial and services group engaged in the energy and environment sectors. Electrabel employs

approximately 4,800 people and has a generating capacity of 9,020 MW. The company operates seven nuclear reactors in Belgium, four at Doel and three at Tihange, with a total nuclear capacity of almost 6,000 MW. Tihange is located 95 kilometers southeast of Brussels along the Meuse River. Tihange 1 is a three-loop Pressurized Water Reactor (PWR) with an electrical output of 962 MW. The plant was commissioned in 1975 and, on July 4, 2012, the Belgian government decided to extend the operational life of Tihange 1 by 10 years until 2025.

L-3 MAPPS has over 30 years of experience in pioneering technological advances in the marine automation field and over 40 years of experience in delivering high-fidelity power plant simulation to leading utilities worldwide. In addition, the company has more than four decades of expertise in supplying plant computer systems for Canadian heavy water reactors. L-3 MAPPS also provides targeted controls and simulation solutions to the space sector. To learn more about L-3 MAPPS, please visit the company’s website at www.L-3com.com/MAPPS.

Headquartered in New York City, L-3 employs approximately 38,000 people worldwide and is a leading provider of a broad range of communication and electronic systems and products used on military and commercial platforms. L-3 is also a prime contractor in aerospace systems. The company reported 2015 sales of \$10.5 billion. To learn more about L-3, please visit the company’s website at www.L-3com.com.



Tihange 1 Full Scope Simulator Inauguration Ceremony (September 21, 2016). Simulator Ribbon Cutting by (from left to right) Guy Pironet, Tihange 1 LTO Program Director, ENGIE Electrabel, Naïm Shita (Tihange 1 Simulator Project Manager, ENGIE Tractebel) and Philippe Lemaire (Tihange Operations Director, ENGIE Electrabel).

Dear Editor,

Re: Fred Boyd's letter on "Infamous Anniversaries: Learning from Severe Accidents", June 2016 edition.

Genesis of two safety shutdown systems in CANDU

Fred Boyd's recollection of the genesis of the concept of two independent shutdown systems is basically correct except that the project in question was the CANDU-BLW 250 (Gentilly-1) reactor project not Bruce A and the chief project manager with which the AECB dealt was AECL's George Pon, not Ontario Hydro's Bill Morison. Bruce A came later.

During this period, late-1960s, I was the AECB's project officer and on-site inspector for both Pickering A and Douglas Point. We project officers were spread pretty thinly in "them days" and project officers from one project were expected to help in the review of projects other than their own. I attended meetings involving the licensing of the CANDU-BLW 250 and contributed to the AECB's review. By the time Bruce A was nearing operation in the mid-1970s I was Chief of the Reactor and Accelerator Licensing Division which made recommendations to the AECB board members on licensing of reactor projects.

The CANDU-BLW 250 was an AECL-designed-and-owned project to be operated by the power utility [*Hydro Québec*] as was the earlier CANDU-PHWR at Douglas Point [*Ontario Hydro*]. CANDU-BLW 250 was a CANDU reactor with vertical pressure tubes, natural uranium fuel and boiling light water whose steam was fed directly to the steam generator in another building. It was under construction at Gentilly when the designers received information from the UK Atomic Energy Authority (UKAEA) that one of the "conservative" assumptions behind a loss-of-coolant accident analysis was terribly wrong. It had been assumed by AECL that, during a loss-of-coolant accident, the reactor fuel would heat up "conservatively" assuming a zero heat transfer [to the coolant]. With this assumption their analyses showed that the public would be adequately protected.

What the UK information showed is that heat transfer to the coolant voided the core faster with an exponentially faster rate of power increase. The UKAEA was developing its Steam Generating Heavy Water Reactor (SGHWR) was superficially similar to the CANDU-BLW 250, but using slightly enriched uranium fuel the former had an almost zero positive void coefficient of reactivity, whereas, the latter had a quite a large positive void coefficient.

The situation at the CANDU-PHWRs was not as severe because the void coefficient of reactivity is much smaller than for the CANDU-BLW 250. Nevertheless, the ability of the containment to deal with a reactor runaway to destruction was in doubt so the same route of providing a second diverse and independent SSD was followed in Bruce A and later.

In the end the history of two diverse and independent SSD demonstrates the risk-informed approach to safety. The Canadian approach, the result of constructive intercourse

between the regulator and the licensee, was aimed at reducing the probability of such severe accidents rather than trying to cope with them.

John Beare

Kanata, ON Canada

Dear Editor,

Re: Paper in June 2016 Bulletin "Radiation by the Numbers: Developing an On-Line Canadian Radiation Dose Calculator as a Public Engagement and Education Tool"

I have been studying the above noted article in the CNS Bulletin and I find this to be a very seriously misleading paper. The problems include the following: the use of the term 'banana' is silly; the use of seven-figure results implies far greater accuracy than is justified; and, the use of 'Canadian average' is quite misleading for use in many locations such as Elliot Lake, Port Hope or South March.

Many options seem to be ignored, such as smoking but not inhaling, smoking a whole pack each day, spending a lot of time (or no time) in a basement.

Perhaps most important, it attempts to draw serious attention to a non-problem that scares many people, for wrong reasons.

I would urge that this project be abandoned.

Don Wiles

Ottawa, ON Canada

Dear Editor,

Re: Response to letter from Don Wiles, re: "**Radiation by the Numbers: Developing an On-Line Canadian Radiation Dose Calculator as a Public Engagement and Education Tool**"

Fear and concern about radiation is at the root of anti-nuclear sentiments – 60 years of experience has demonstrated that ineffectively communicating about radiation by not talking about it has not helped nuclear power's image.

The Canadian Radiation Dose Calculator is intended to be, first and foremost, a tool for initiating conversations about a topic that is elusive to grasp. The calculator makes use of the information that is available, such as using both Canadian averages and information for a selection of specific localities. Reasonable selection and assumptions had to be made. For example, inhalation dose is based on a combination of indoor and outdoor exposures based on the amount of time that an average person spends inside and outside.

The calculator is unapologetically a work in progress. However, it is hoped that it can be a tool that can help increase understanding. Additional data and constructive suggestions are always welcome.

Matthew Dalzell

Sylvia Fedoruk Canadian Centre for Nuclear Innovation

Seismic Fragility Analysis of a Nuclear Building based on Probabilistic Seismic Hazard Assessment and Soil-Structure Interaction Analysis

by R. GONZALEZ¹, S. NI¹, R. CHEN¹, X. M. HAN¹, and D. MULLIN²

[Ed Note: The following paper was presented at the 36th Annual Conference of the Canadian Nuclear Society and 40th Annual CNS/CNA Student Conference, Toronto Marriott Downtown Eaton Centre Hotel, Toronto, ON, Canada, June 19-22, 2016.]

Abstract

Seismic fragility analyses are conducted as part of seismic probabilistic safety assessment (SPSA) for nuclear facilities. Probabilistic seismic hazard assessment (PSHA) has been undertaken for a nuclear power plant in eastern Canada. Uniform Hazard Spectra (UHS), obtained from the PSHA, is characterized by high frequency content which differs from the original plant design basis earthquake spectral shape. Seismic fragility calculations for the service building of a CANDU 6 nuclear power plant suggests that the high frequency effects of the UHS can be mitigated through site response analysis with site specific geological conditions and state-of-the-art soil-structure interaction analysis. In this paper, it is shown that by performing a detailed seismic analysis using the latest technology, the conservatism embedded in the original seismic design can be quantified and the seismic capacity of the building in terms of High Confidence of Low Probability of Failure (HCLPF) can be improved.

Keywords: Seismic fragility, risk assessment, seismic hazard, ground motion, uniform hazard spectra, soil-structure interaction, dynamic model, CANDU 6.

1. Introduction

A Probabilistic Seismic Hazard Assessment was performed in 2015 that provided a Uniform Hazard Spectra (UHS) to represent the seismic hazard for Point Lepreau Generating Station (PLGS). Foundation Input Response Spectra (FIRS) was calculated for key safety-related buildings of the plant considering site-specific geological conditions [1].

The original seismic design for PLGS in the 1970s was based on a typical Canadian Standard Association spectral shape with anchorage to a peak ground acceleration of 0.2g. The Design Basis Earthquake (DBE), defined for a hazard equivalent to an approximate 1 in 1,000-year return period, is energy rich in the frequency range from 2.7 to 7 Hz. However, the FIRS, calculated for a total hazard at a mean 10,000-year return period (i.e. mean Annual Frequency of Exceedance of $1E-04$), has a PGA of 0.344g and is energy rich in the

high frequency range that is greater than 10 Hz. The DBE and FIRS are presented in Figure 1.

Updated seismic fragility evaluations are required based on the FIRS. The fragility analysis method, documented in EPRI Report TR-103959 [2] is followed to calculate the median seismic capacities of the critical failure modes of the building and their associated variability. High Confidence of Low Probability of Failure (HCLPF) calculation for the service building division II is presented in this work.

The scaling method suggested in EPRI reports [3] & [4] to make use of previous analysis results are not applicable because of the difference in the UHS and DBE spectral shapes. In addition, “as built” structure drawings including some modifications completed during the service life of the structure are used for the seismic fragility evaluation.

2. Service Building Division II Description

The service building division II is part of the structural complex adjacent to the reactor building that contains all supporting services for the equipment in the reactor building. The service building division II consists of a reinforced concrete substructure and a steel superstructure with floors composed by steel beams embedded in concrete. The building has a semi-circular shape on the side facing the reactor building. The approximate dimensions in plan are 41 m x 25 m. It is approximately 15 m tall from elevation 13.72 m (45 ft, the grade level of the plant), as shown in Figure 2. The service building division II comprises of: a floor at elevation 13.72 m (45 ft), a floor at elevation 22.94 m (75 ft - 3 in), a roof at elevation 28.73 m (94 ft - 3 in) and, a one story basement at elevation 7.62 m (25 ft). The roof supports some small steel superstructures: one for pipe supports and cable tray housing, another one for a filter room and the stairs enclosure.

-
- 1 Candu Energy Inc. - member of the SNC-Lavalin Group, Mississauga, Ontario, Canada
 - 2 New Brunswick Power, Point Lepreau, New Brunswick, Canada

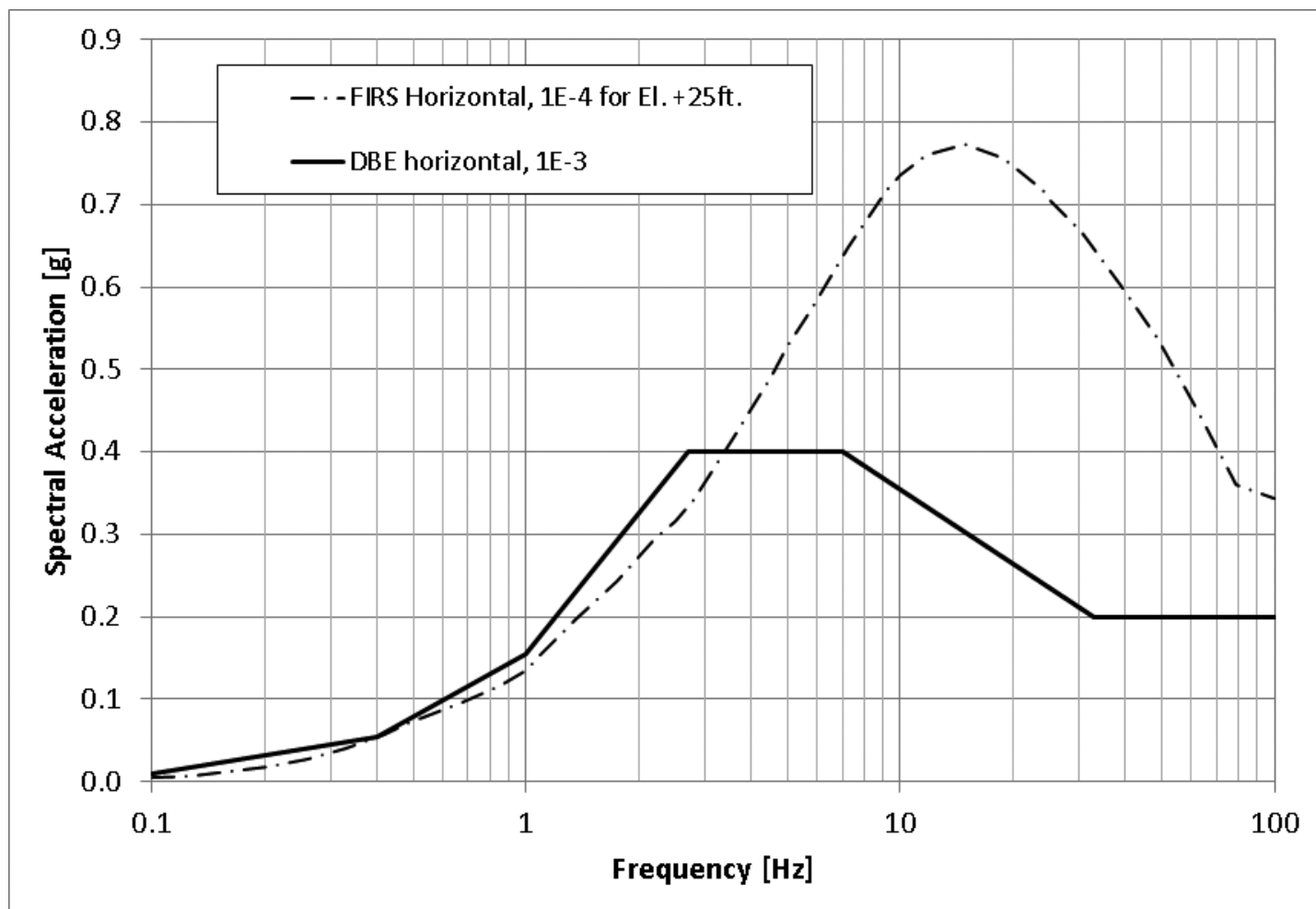


Figure 1: Comparison between PLGS Design Basis Earthquake, and Foundation Input Response Spectrum at a Mean Annual Frequency of Exceedance of 1E-04

3. Seismic demand

Soil Structure Interaction (SSI) analyses are conducted by the sub-structuring approach implemented in the computer program ACS SASSI [5]. It uses linear finite element modelling and the frequency domain solution methods. The complex soil-structure system is partitioned into two sub-structures, namely, the foundation and the structure. In this partitioning, the structure consists of the upper-structure plus the basement minus the excavated soil and the foundation consist of the soil layers including the excavated soil. Each sub-problem is solved separately and the results are combined in the final step of the analysis to provide the complete solution using the principle of superposition. The interaction occurs at all excavation volume nodes if the flexible volume method is selected or at the structure-soil interface nodes if the interface method is selected.

3.1 Mathematical model

A finite element model of service building division

II, including post built additions to the structure is developed for soil structure interaction analyses. The model is built by using the computer program ANSYS [6], to take advantage of its excellent modelling capabilities, and then is transferred to ACS SASSI. Selection of element types and sizes are according to recommendations in ACS SASSI reference manual.

Openings indicated in structural drawings are accounted in the model. Enclosing walls are modelled through mass elements; their stiffness is neglected by engineering judgement. All main structural connections are considered to be hinge connections as assumed for the original structural design.

Snow mass and the roof mass are accounted through mass elements at the roof corner nodes per tributary area. Figure 2 shows the finite element model of the service building division II. The excavated soil in the embedded portion of the model is included in the model for soil structure interaction analysis. The soil is represented by solid type elements with sizes up to 1.0 m in vertical direction. Nine layers are modelled within the embedded portion of the model.

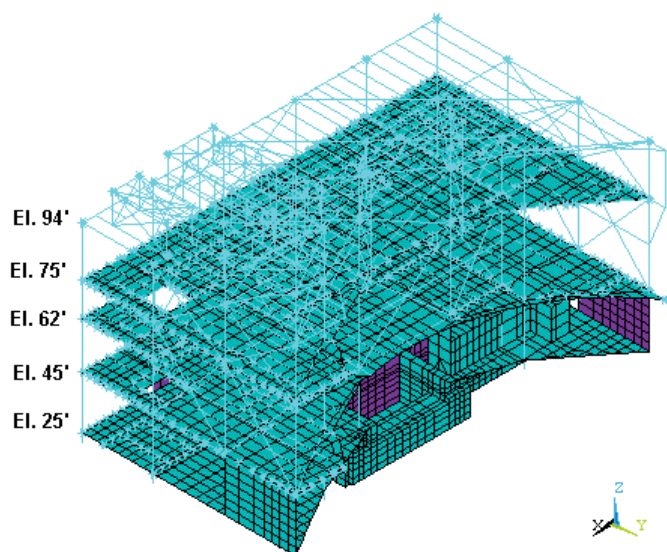


Figure 2: Service Building Division II Finite Element Model

3.2 Foundation medium

The plant is sited on competent rock. The stiffness of any soil above elevation 7.62 m (25 ft) is not accounted for in the analysis with conservative engineering judgement. The foundation medium is modelled using discretized soil layers overlying a uniform elastic half space.

3.3 Modal analysis

Modal analysis is conducted in ANSYS to compute the main mode frequencies of the service building

structure. The boundary condition analysed is the fixed-base. The model is fixed at elevation 7.62 m (25 ft) for modal analysis. The fixed-base natural frequencies give some insights on the approximate location of the peaks in the transfer functions to be computed in the SSI analyses and allow model checking after transferring it to ACS SASSI. Table 1 presents the main frequencies comparison between the fixed-base model and SSI model. The main frequencies in both analyses are very similar because the soil profile is hard rock. As expected, the structural dynamic behaviour indicates that the steel superstructure is more flexible than the concrete portion of the structure. The vertical modes are more localized than the horizontal modes as can be concluded from the mass participation.

3.4 Seismic input

The seismic inputs for the seismic analyses are acceleration time histories in three perpendicular directions compatible with the FIRS. The time histories meet the acceptance requirements in CSA N289.3 [7] and tightly match the FIRS developed at elevation 7.62 m (25 ft) based on site response analysis [1]. In addition, the site response analysis is developed based on the UHS at the bedrock level developed in the probabilistic seismic hazard assessment.

The control point or location of the seismic input is selected at elevation 7.62 m (25 ft). The time-step of all input time-histories is 0.005 seconds. The time-histories are defined by 8192 points including a quiet zone. In the frequency domain, this translates to a frequency increment of $\Delta f = 1 / (0.005 * 8192) = 0.0244$ Hz.

Table 1 Main Frequencies of Service Building Division II

Mode Number	Frequency Fixed base model (Hz)	Frequency SSI Model (Hz)	Direction	Remarks	Mass Participation Fraction
2	2.6	2.6	Y (A-C)	Steel Structure	29%
3	2.7	2.8	X (B-D)	Steel Structure	36%
7	3.6	3.5	Z (Vertical)	Steel St. (local mode)	1%
14	4.9	5.0	Z (Vertical)	Steel St. (local mode)	2%
21	5.5	5.5	Z (Vertical)	Steel St. (local mode)	2%
125	8.3	7.5	Y (A-C)	Concrete Structure	4%
172	10.3	9.6	X (B-D)	Concrete Structure	14%
233	13.4	13.4	Z (Vertical)	Concrete Structure	2%

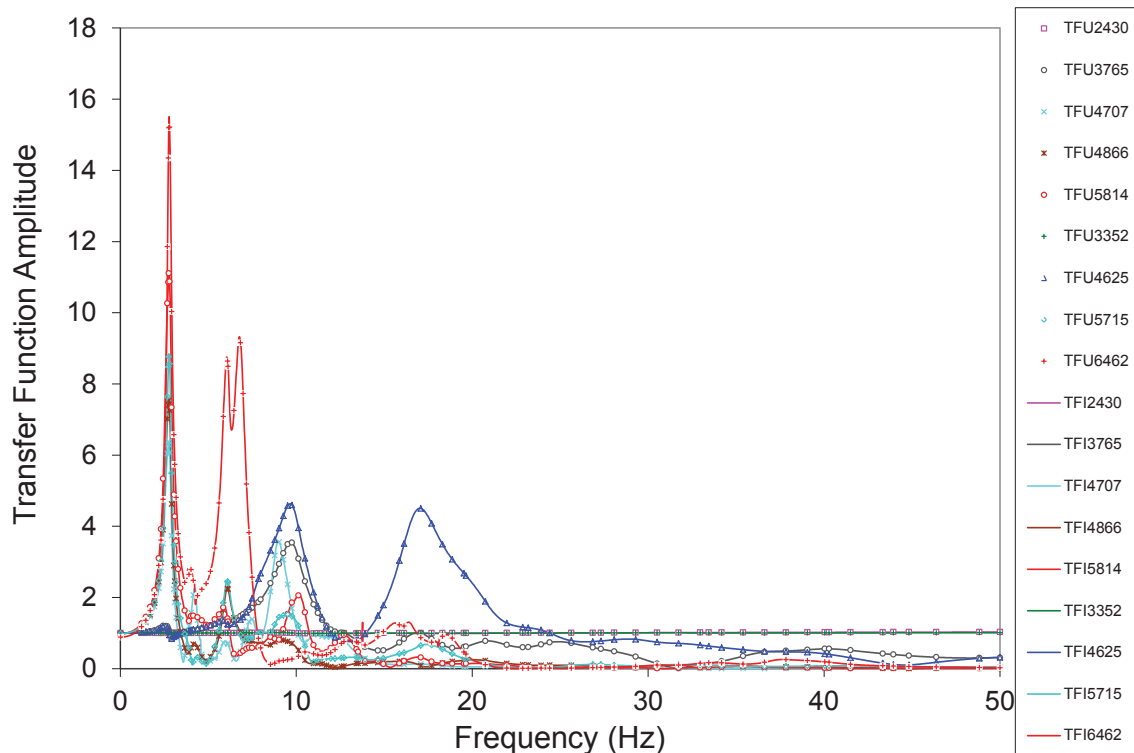


Figure 3: Transfer functions for B-D (X) direction

3.5 Cut-off frequency

The cut-off frequency used in the analysis is 50 Hz; it is assessed by ensuring that the computed transfer functions are satisfactory up to the selected cut-off frequency. The transfer functions are computed at discrete frequency points. Interpolation schemes implemented in ACS SASSI program are used to compute interpolated transfer functions from the discrete transfer functions. A large number of frequency points (97) are used in the SSI analyses for the computation of transfer function curves to ensure that the interpolated transfer functions are well defined over the frequency range of interest following recommendations in Reference [5]. Figure 3 shows transfer functions at some nodes, for the analysis of the structure, in B-D horizontal direction. The blue and black curves show transfer functions of nodes located in the concrete substructure and the red and light blue show transfer functions of nodes located on the steel structure.

3.6 Seismic results

Floor response spectra, variation of structural acceleration and displacement along the height, and seismic forces in structural members are calculated for two horizontal directions each in combination with the vertical direction. The floor response spectra are generated in three orthogonal principal directions for five critical damping values including 2%, 4%, 5%, 7% and 10%.

Floor response spectra and displacements are the

seismic inputs for fragility calculations of system and components in service building division II, while the seismic forces represent the seismic demands for fragility calculations of the structure.

The most stressed structural elements in the steel structure of the service building are the columns and bracing system between elevations 13.72 m (45 ft) and 22.86 m (75 ft). The bracing system along the grid lines “H” and “K” resists the highest seismic loads for the UHS seismic input. Consistently, the bracing system along the grid lines “H” and “K” presented the highest seismic forces for the DBE seismic input. Figure 3 shows grid lines and the columns location. Figures 4 to

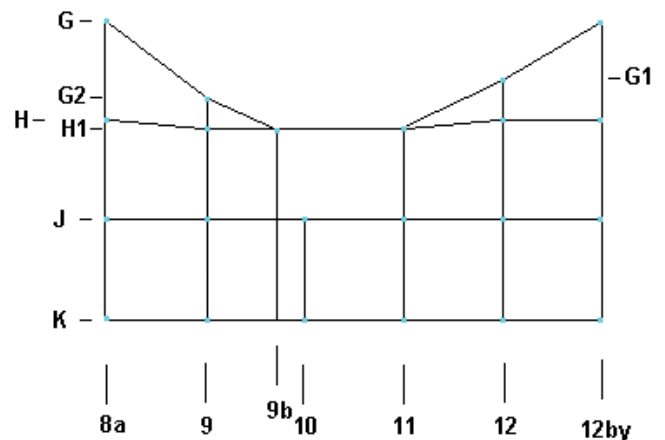


Figure 4 SB Division II main columns location

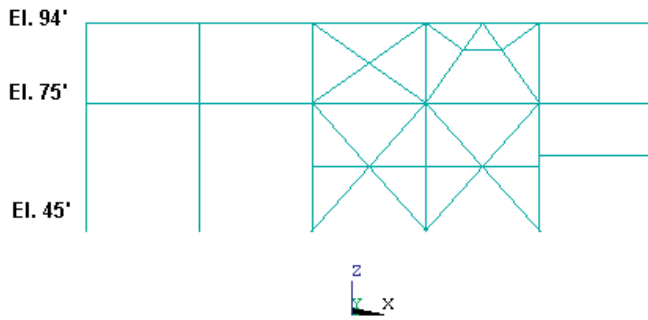


Figure 5 Section at Grid Line "K"

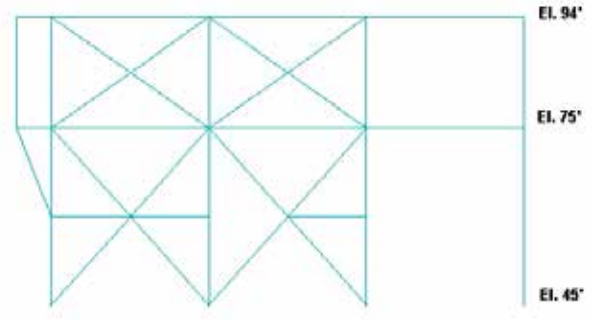


Figure 6 Section at Grid Line "8a"

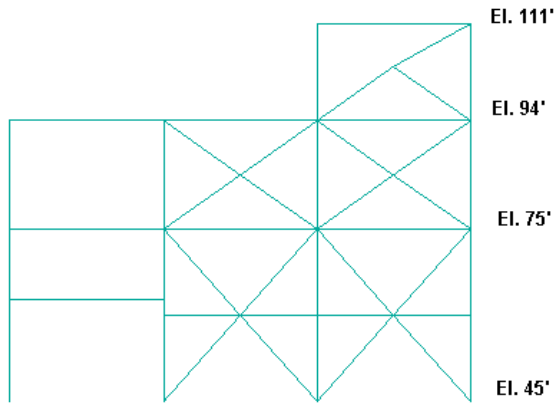


Figure 7 Section at Grid Line "12by"

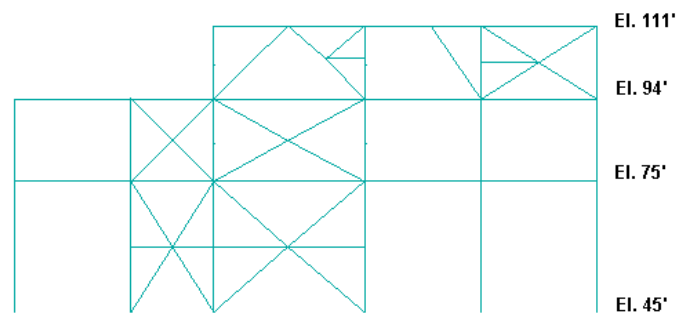


Figure 8 Section at Grid Line "H-H1"

7 present the structure main frames configuration.

The seismic forces calculated through the SSI analysis based on UHS are about 25% to 40% lower than the seismic forces based on the DBE seismic input used for the structure design. The forces distribution among members was similar in both analyses.

4. Structure seismic capacity

The seismic capacity or fragility is defined as the conditional probability of failure that the structural response exceeds the structural capacity or resistance for a given peak ground acceleration. The methodology documented in EPRI Report TR-103959 [2] is followed to calculate the median seismic capacity of the building and its associated randomness and uncertainty variability.

The median seismic capacity is quantified by the High Confidence of Low Probability of Failure (HCLPF) value, which represents, with a 95% confidence, that the probability of failure of the structure will not exceed 5%. It is calculated by:

$$\text{HCLPF capacity} = A_m \exp \left[-1.65 \left(\beta_R + \beta_U \right) \right] \quad (1)$$

The family of seismic fragility curves may be described by these three parameters, i.e., A_m , β_R and β_U , where,

A_m : is the median capacity and β_R and β_U are the variability defined in terms of randomness and uncertainty, respectively.

$$A_m = F \cdot A_{UHS} \quad (2)$$

Where, A_{UHS} is the peak ground acceleration for the UHS and F is the median factor of safety for an identified mode of failure.

The median factor of safety and variability are calculated for factors listed below. The overall factor of safety (F) is the product of all factors of safety. The overall randomness and uncertainty is the square root of the sum of squares of all randomness and uncertainty values.

The capacity factor considers

$$F_C = F_S \cdot F_p \quad (3)$$

- Strength Factor (F_S)
- Inelastic Energy Absorption Factor (F_p)

The structural response factor (F_{SR}) is based on:

$$F_{SR} = F_{SH} \cdot F_D \cdot F_M \cdot F_{MC} \cdot F_{EC} \cdot F_{GMI} \cdot F_{SSI}$$

- Spectral Shape Factor
- Damping Factor
- Modeling Factor
- Modal Combination Factor
- Earthquake Components Combination Factor
- Ground Motion Incoherence Factor
- Soil-Structure Interaction Factor

F is represented by:

$$F = F_C \cdot F_{SR} \quad (4)$$

$$\beta_R = (\beta_{RC}^2 + \beta_{RSR}^2)^{1/2} \quad (5)$$

$$\beta_U = (\beta_{UC}^2 + \beta_{USR}^2)^{1/2} \quad (6)$$

β_{RC} = logarithmic standard deviation due to randomness associated with seismic capacity factor, it is the square root of the sum of squares of the randomness of the strength and inelastic energy absorption factors.

β_{RSR} = logarithmic standard deviation due to randomness associated with structure response factor, it is the square root of the sum of squares of the randomness of every factor accounted for the structural response factor.

β_{UC} = logarithmic standard deviation due to uncertainty associated with seismic capacity factor, it is the square root of the sum of squares of the uncertainty of the strength and inelastic energy absorption factors.

β_{USR} = logarithmic standard deviation due to uncertainty associated with structure response factor, it is the square root of the sum of squares of the uncertainty of every factor accounted for the structural response factor.

4.1 Failure modes in the service building

The reinforced concrete service building substructure is massive and seismically rugged. The superstructure however is a steel braced frame structure with pinned joints. The structure seismic analysis results indicated that the bracing system and columns between elevations 7.62 m (45 ft) and 22.86 m (75 ft) carry most of the seismic forces.

The bracing system along grid line “K” between grid lines 11 and 12 is selected for seismic fragility calculations considering the high acting seismic load and the largest slenderness ratio. Buckling of a diagonal bracing of this frame is judged to be one of the potential critical failure modes.

The connection between the diagonal member and the beam/column is another potential critical failure mode and, anchoring failure of columns base experiencing uplift forces is another potential failure mode that is reviewed in the service building seismic fragility calculations.

4.2 Capacities per failure mode

The capacities for each individual failure mode are determined and expressed in terms of the same parameters as the demands (i.e., forces, spectral accelerations). The seismic capacities are formulated as the products of the strength and inelastic energy absorption factors.

Axial compression capacity of the bracing member relative to the seismic axial compression demand gives a strength factor of 3.58 for the buckling of the selected bracing member. Seismic fragility calculations for DBE seismic input consistently showed a lowest strength factor of 1.71 obtained for buckling of the selected diagonal member, among other modes of failure evaluated.

Buckling of the bracing gives the lowest calculated factor of safety among the three evaluated modes of failure and therefore is assumed to be the dominant failure mode of the structure.

However; immediately after the bracing buckles in compression the seismic load is expected to be re-distributed to the remaining cross bracing which is in tension at that time. It is, therefore, a post buckling capacity that increases the structure strength for seismic fragility calculation. An inelastic energy absorption factor of 2 for tensile failure is then considered per ASCE 43-05 [8].

4.3 Seismic fragility calculation

Following the methodology above, seismic fragility calculations based on DBE seismic forces resulted in a service building division II HCPLF of 0.42g.

The total factor of safety, calculated as the product of all factors of safety is $F=8.26$, and the combined randomness and uncertainty variability are $\beta_R=0.23$ and $\beta_U=0.42$. Therefore, $A_m=2.84g$ and the service building division II HCLPF is estimated to be 0.98g for a Peak Ground Acceleration of 0.344g from the FIRS that was derived from the Uniform Hazard Spectra.

The improvement in HCLPF obtained for the FIRS seismic input compared with the DBE seismic input is gained from different sources:

- The fact that the seismic input is rich in high frequency but low at the structure main range of frequencies (between 2 and 4 Hz) causes a decrease in the seismic forces imposed on the structure compared to the DBE seismic forces.
- The conservatism embedded in the building original design related to the selection of structural member sizes.

5. Conclusions

In this work, the seismic fragility of the service building division II structure is calculated. The analysis is based on a finite element model and soil structure interaction analysis. The soil structure interaction effects are idealized using frequency-dependent impedance functions for the best estimate soil properties at the site.

Time histories that tightly match the UHS at the foundation level for Point Lepreau Generating Station is the seismic input used in the seismic analyses. The uniform hazard spectrum and foundation input response spectrum is rich in high frequency content which differs from the design basis earthquake. The floor response spectra and seismic forces in the structure are determined for use in seismic fragility calculations of the building. The UHS and foundation seismic input resulted in lower forces than the design forces by about 25 to 40%.

The critical elements in the structure are identified and the probability of failure is calculated. The resulting HCLPF value based on the UHS at the foundation level was determined to be higher than the HCLPF calculated in previous service building seismic fragility calculations that were based on a spectrum derived by scaling up the DBE to reflect a higher seismic demand for the 2008 Point Lepreau PSA-based Seismic Margin Assessment.

The main frequencies for the steel superstructure are between 2 and 4 Hz. Therefore, the structure is more stressed during a design basis type of earthquake than the uniform hazard type of earthquake even though the peak ground acceleration is higher for the latter (0.2g vs. 0.344g) and the probability of exceedance is about an order of magnitude lower for the UHS than the DBE type of earthquake.

The service building division II high confidence of low probability of failure (HCLPF) is 0.98g for the uniform hazard spectrum in contrast to 0.42g as calculated for the 2008 Point Lepreau PSA-based Seismic Margin Assessment. The results demonstrate that;

- (a) relative flexible structures such as the steel super structure of the service building division II are not affected adversely by high-frequency motions;
- (b) the service building division II seismic design for sites with seismic earthquakes rich in high frequency content and hard rock foundation condition is robust; and,
- (c) detailed finite element modelling of the building is an efficient way to remove the conservatism embedded in the original simplified design.

6. References

- [1] J. K. Kimball, J. E. Blanco, W Li, S. Ni, R. Chen, M. Han and D. Mullin. "Key technical issues when developing probabilistic foundation input response spectra for seismic analysis" 36th Annual Conference of the Canadian Nuclear Society and 40th Annual CNS/CNA Student Conference, Toronto, ON, Canada, June, 2016.
- [2] EPRI TR-103959, "Methodology for Developing Seismic Fragilities", Final Report, June 1994.
- [3] EPRI 1025287 Screening, "Prioritization and Implementation Details (SPID) for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic", November 2012.
- [4] EPRI NP-6041-SLR1 "A Methodology for Assessment of Nuclear Power Plant Seismic Margin (Revision 1)".
- [5] ACS SASSI Version 2.3.0, Ghiocel Predictive Technologies, "An Advanced Computational Software for 3D Dynamic Analysis Including Soil-Structure Interaction", User Manual, Revision 1.0, Ghiocel Predictive Technologies, June 2009.
- [6] ANSYS "Finite Element Analysis Program", Release 11.0, ROI Engineering Inc., Canonsburg, Pennsylvania, US.
- [7] CSA N289.3-10, "Design procedures for seismic qualification of nuclear power plants - Second Edition", 2010.
- [8] ASCE/SEI 43-05 "Seismic Design Criteria for Structures Systems and Components in Nuclear Facilities".

CNSC invites comments on draft REGDOCs

Draft REGDOC-1.1.1, *Licence to Prepare Site and Site Evaluation for New Reactor Facilities*.

The Canadian Nuclear Safety Commission (CNSC) is asking the public to provide their comments on draft REGDOC-1.1.1, *Licence to Prepare Site and Site Evaluation for New Reactor Facilities*.

This document sets out requirements and guidance for site preparation and site evaluation for new nuclear power plants and small reactor facilities. It also provides requirements and guidance for a licence to prepare site. The lifecycle phases of construction and operation are also addressed.

Once published, this document will supersede RD-346, *Site Evaluation for Nuclear Power Plants*. REGDOC-1.1.1 has revised the content of RD-346 to:

- clarify requirements and guidance language
- expand scope to include small reactor facilities using a graded approach
- include site preparation requirements and guidance

REGDOC-1.1.1 also incorporates lessons learned from the Fukushima nuclear event of March 2011. Amendments were made to address findings from **INFO-0824, CNSC Fukushima Task Force Report**, and the subsequently issued action plans as applicable to RD-346.

REGDOC-1.1.1 is part of the CNSC's reactor facilities series of regulatory documents, which also includes licence application guides for licences to construct, operate and decommission nuclear power plants.

A request for information specific to this document is also included, which outlines the regulatory objectives and approach, as well as the potential impacts on stakeholders.

The public is asked to provide clear and specific feedback to help CNSC staff refine, or revisit, initial assumptions and objectives.

To review and comment on the document and request for information, visit the **REGDOC-1.1.1 webpage**. Please submit your feedback by November 12, 2016. Comments submitted, including names and affiliations, are intended to be made public.

Contacts

Aurèle Gervais
Media and Community Relations
Canadian Nuclear Safety Commission
613-996-6860
1-800-668-5284
cnsccmediarelations-relationsmedias.ccsn@canada.ca

Dose Limits to the Eye Lens

by NICHOLAS SION

[Ed. Note: The following paper was submitted to the Bulletin by the author.]

1. Introduction

Protecting the human body from the effects of ionizing radiation is essential to forestall stochastic¹ effects and require placing limits on the effective dose. Dose limits on specific organs are also necessary to reduce the deterministic² effects and tissue reactions.

The standard for radiation protection was ISO 15382 (2002) which mainly dealt with beta radiation for nuclear power plant workers. Clearly an update is required to allow for new technology and the proliferative use of radiation in medical practices. There is a need for more explicit radiation monitoring to operators and staff. ICRP118 (International Commission on Radiological Protection), Ref. 1, evolved their recommendations to include eye lens doses as a follow on to their publication 103 and to focus on radiation exposures. It provides updated estimates of 'practical' threshold doses for tissue injury at the level of 1% incidence.

This paper discusses the current status and the recommendation for a drastic reduction of the dose limit to the eye lens.

2. Typical Workplace Exposures

In workplace situations, radiation fields can be predictable when measured over long periods, if its variability is minimal, and thence worker doses can be estimated. In medical practices the annual doses can be as shown in Table 1 measured by a whole body dosimeter. But If the dosimeter is worn under protective shielding it will underestimate the dose to the unshielded surfaces, such as the eyes. Of concern, is the inducement of cataract which is the loss of transparency of the lens of the eye which lies behind the iris and the pupil Fig. 1 and starts with lens opacities, Fig. 2. Cataracts may be induced by genetic components, is age related, and is exacerbated by additional factors viz. too much sunlight (UV), imbibing, smoking, diabetes, the use of corticosteroids, and of course by radiation.

Clinical data have shown that radiation associated posterior lens opacities was 52% for interventional

Table 1: Medical Practice Exposures

Operator/Worker	Annual Dose Range in mSv
Nuclear Medicine Staff	5-40
Interventional Radiologists (hands)	10-200
Interventional radiologists (legs)	10-200
Interventional radiologists (legs with shield)	1-15
Cardiologists (hands)	5-100
Cardiologists (legs)	5-100
Cardiologists (legs with shield)	0.5-10

Source: IRPA14 Lecture Notes by Filip Vanhavere

cardiologists, 45% for nurses, and 9% for controls, Ref. 2. Estimated cumulative ocular doses ranged from 0.01Gy to 43Gy. This Indicated a strong dose-response relationship of increased risk of the posterior lens opacities for interventional cardiologists and nurses when radiation protection tools are not used.

3. Regulating the Exposure from Ionizing Radiation

The epidemiological evidence suggest that the threshold absorbed dose for the induction of deleterious effects on the eye lens is about 0.5 Gy, Ref. 3, and summarized in Table 2. Based on this finding, the International Commission on Radiological Protection (ICRP) recommends that the dose equivalent to the eye lens should be reduced from 150 mSv to 20 mSv in a year, averaged over a 5y period with exposure not exceeding 50 mSv in any single year. On 21 April 2011 the ICRP recommendations followed their statements on tissue reactions by stating it is more appropriate to treat cataract induction as a stochastic rather than as a deterministic effect. The ICRP recommendations are summarized in Table 3. Hence, within this context, it is illogical to apply the same dose limit for a uniformly

-
- 1 Stochastic effects are the non-lethal transformation of cells that can still cell divide, but can lead to cancer after a latency period if it is a somatic cell, or may lead to hereditary effects if it is a germ cell. It is proportional to the dose received with no threshold. The 'detriment-adjusted nominal risk coefficient of dose', which includes the risks of all cancers and hereditary effects, is 5% per Sievert (Sv). Ref. 4.
- 2 Deterministic effects are clinically observable when the dose exceeds a certain threshold and where the severity increases with increasing dose. Examples include radiation burns, hair loss, cataracts, nausea, and such radiation caused symptoms.
-

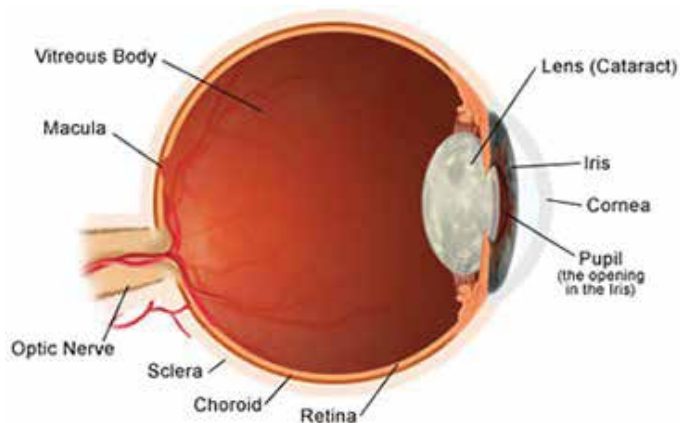


Fig. 1 Eye Schematic with Cataract Lens

irradiated whole body to the lens of the eye. There are two possibilities to address this issue viz.

- a- Assigning an appropriate tissue weighting factor to the dose limit of the eye lens, and including it in the computation of the effective dose, or
- b- By having a composite approach involving the use of a tissue weighting factor for effective dose computations together with a special limit on the equivalent dose to the lens of the eye.

This approach would ensure that no individual would be subjected to an unacceptably high risk of inducing clinically significant cataracts. The IAEA Ref. 4, has developed two safety guides viz. Radiation Safety in the Medical Uses of Ionizing Radiation No. RS-G-1.5; and Occupational Radiation Protection IAEA Safety Standards Series No. RS-G-1.1 to provide guidance on the control of occupational exposures in the medical and other fields where there is harmful ionizing radiation.

The rationale for not including the equivalent annual dose limit of 500 mSv in the 20 mSv effective dose limit is based on preventing deterministic effects to the skin. Ref. 5.

Recent occupational findings in chronically radiation exposed workers suggest there is a long term risk for cataracts and the need for eye protection even at low doses. In 2012 IRPA formed a Task Group (TG) to assess the impact of a reduced dose limit to the eye lens for occupational workers. The TG proposed the following:

- Reduce the number of sessions the staff can do per year in order to keep within the new dose limit.
- Continue using the available protective measures

Table 2: ICRP118 Estimates for Threshold Doses

Effect	Organ Tissue	Time to Develop Effect	Acute Exposure Gy	Highly Fractionated (2Gy fractions or equivalent)	Annual Dose Rate over many years
Cataract	Eye	> 20 y	~ 0.5	~ 0.5	~ 0.5



Normal Eye

Cataract Eye



Fig. 2 Vision by Normal Eye and by Cataract Eye

but ensuring their optimum usage.

- Increase risk awareness to potentially exposed workers. This can be achieved by mentoring, training, and by implementing a safety culture.

However, in the nuclear power industry there is the alternate methodology of placing the operator in a remote location. Yet, issues prevail in the implementation of the new recommendations of dose reduction Ref. 6. Ontario Power Generation (OPG) identified issues requiring higher dose limits and has brought it to the attention of Regulatory authorities. There is the potential for extra costs in training programs and changes in work methods. On the positive side, increasing the use of robotics have reduced the dose significantly.

Equipment to Reduce Dose

Some manufacturers have developed special equipment, such as Cathpax CRT Fig. 3, and Lemer Pax Fig. 4 which are more like radiation shielding cabins dedicated to procedures under fluoroscopy. The Cathpax® provides optimal radiation protection and obviates the need, and the discomfort, of a lead apron.

4. Dosimetry

5.1 Eye Lens Exposure to Photon Radiation

This is more applicable in the medical field in

Table 3 :ICRP Recommended Dose Limits

Type of Limit	Occupational Exposure	Exposure to Public
Annual Effective Dose	20 mSv/y averaged over 5y ¹	1 mSv/y
Annual Equivalent Dose: Eye Lens	20 mSv/y averaged over 5y ¹	1 mSv/y
Skin ² Hands and Feet	500 mSv 500 mSv	50 mSv 50 mSv
1 Provided that the Effective Dose does not exceed 50 mSv in any single year. Additional restrictions apply to the occupational exposure of pregnant women. 2 Averaged over 1 cm ² area of skin regardless of the area exposed. Public dose limit stays at 15 mSv/y NASA limit of 8 mSv in total for astronauts on a mission		

**Fig. 3** Cathpax CRT**Fig. 4** Lemer Pax

interventional radiology where exposure to x-ray fields of <150 keV occur. This exposure is mainly from scattered radiation emanating from the patient who is undergoing an examination. Data show that with exposure to high-energy photons (> 200 keV), it can be assumed that the dose equivalents Hp(10) provides a good estimate of the eye lens dose. Ref. 7.

Table 4: Types of Dosimeters

Depth (d) in mm	Hp(d) is for estimating	Annual Limit mSV	Typical usage Ref. 7
Hp(10)	Equivalent dose, E	20	Gamma and X-Ray [i]
Hp(3)	Equivalent Eye Dose, H _{lens}	150	Medical applications and for close work, fluoroscopy [ii]
Hp(0.07)	Equivalent Skin Dose, H _{skin}	500	Photon radiation fields [iii]
[i] The Hp(10) adequately estimates the eye lens dose at energies of <100 keV. [ii] The Hp(3) is sufficient to determine eye lens dose in interventional applications e.g. cardiology. Must be calibrated on a water slab phantom. [iii] The Hp(0.07) adequately estimates the eye lens dose at energies of <200 keV. Hence there is no need to an additional dose equivalent quantity Hp(3). Must be calibrated on a water slab phantom.			

5.2 Eye Lens Exposure Beta Radiation

Beta particles (electrons) with energies < 3 MeV have low depth penetration in tissue where the dose transmission is localised at the tissue surface. Electrons with energies < 0.7 MeV have a range of < 3 mm tissue depth and therefore do not contribute to the eye lens dose in practice.

Table 4 shows the types of dosimeters, their limits and their usage, derived from Ref. 7. With all the shown overlaps it is recommended that efforts be made to obtain international clarification as to how the eye lens dose be calculated with the advent of Hp(3). In applications of interventional cardiology and radiology, the staff work in close proximity to the x-ray sources. The exposures received are non-uniform because the staff wear lead aprons to shield the body, but the head/eye are not protected. Hence Hp(3) is the recommended dosimeter (IRPA14 Task Group) to provide the Equivalent Dose at 3 mm depth. In nuclear power plants and non-medical centers a whole body dosimeter is considered sufficient. Unfortunately Hp(3) dosimeter is not yet widely available hence both Hp(0.07) and Hp(10) are used. A number of methods of estimating the eye dose based on ratios of Hp(3)/Hp(10) have been proposed for both the nuclear and medical sectors; but are not yet definitive.

In item [iii] of Table 4, the skin dose Hp(0.07) is the dose equivalent in 0.07 mm depth in the body at the application point. The Dose Equivalent $H_{T,R}$ is the product of the organ absorbed dose $D_{T,R}$ averaged over tissue organ T generated by the radiation R and the weighting factor W_R

$$H_{T,R} = W_R * D_{T,R}$$

If the radiation has multiple energies and with different weighting factors then use the summing equation below and pick the appropriate weighting factor from Table 5.

6. Conclusions

- Dose to the eye lens is to be considered as a stochastic and not a deterministic effect.
- A unified international approach is required to clarify how the eye lens dose be calculated.

Table 5: Radiation Weighting Factors for Dose Equivalent

Radiation Type and Energy Range	Radiation Weighting Factor W_R
Photons, all energies	1
Electrons and muons, all energies	1
Neutrons:	
< 10 keV	5
10 keV to 100 keV	10
>100 keV to 2 MeV	20
>2 MeV to 20 MeV	10
> 20 MeV	5
Protons, except for recoil protons, > 2 MeV	5
Alpha particles, fission fragments, heavy nuclei	20

- Can use the HP 0.07 dosimeter where the photon

energy is <200 keV. This is commonly used in interventional radiology.

- Yet, there were calls for the threshold dose to be set at an even lower level, due to clinical evidence. Since the recommendation for a new eye lens dose limit some 5 years ago, a complete resolution of all the practical issues has not been achieved. Such a drastic reduction in dose limit needs time to be implemented. Its application will deeply change previous operating procedures.

References

- Ref. 1 ICRP 118. ICRP Statement on Tissue Reactions / Early and Late Effects of Radiation in Normal Tissues and Organs – Threshold Doses for Tissue Reactions in a Radiation Protection Context, 2012.
- Ref. 2 Risk for Radiation-induced Cataract for Staff in Interventional Cardiology: Is There Reason for Concern? Ciraj-Bjelac O1, Rehani MM, Sim KH, Liew HB, Vano E, Kleiman NJ. PubMed 2010 Nov 15; 76(6):826-34.
- Ref. 3 Regulating Exposure of the Lens of the Eye to Ionising Radiations. M.C. Thorne, J. Radiol.

What is EngineeringCareers.ca?

Brought to you by the Engineering Institute of Canada, **EngineeringCareers.ca** is a job site that connects high-quality professionals with some of the best opportunities in the industry.

What's the benefit?

Expand your reach:

- Access a new pool of qualified Engineers through 11 member Engineering Societies

Save time:

- Resume database search allows you to proactively connect with over 8,500 candidate resumes

Convenient:

- Manage all job postings and applicants from one central location

Save. Source. Hire.

Choose the right services for your hiring needs starting at **only \$300**:

- Job postings
- Resume database access
- Branding and advertising opportunities
- Featured employer packages



Customer Support

Email:

niche.sites@workopolis.com

Toll Free:

1.888.641.4047

Hours:

8:00 AM - 8:00 PM (EST)

The Travesty of Discarding Used CANDU Fuel

by PETER OTTENSMEYER¹

[Ed Note: The following paper was presented at the 36th Annual Conference of the Canadian Nuclear Society and 40th Annual CNS/CNA Student Conference, Toronto Marriott Downtown Eaton Centre Hotel, Toronto, ON, Canada, June 19-22, 2016.]

Abstract

The current plan worldwide for virtually all used nuclear fuels is costly deep burial to attempt to isolate their long-term radiotoxicity permanently. Alternatively Canada's 50,000 tons spent CANDU fuel, of which only 0.74% of the heavy atoms have been fissioned to extract their energy, could supply 130 times more non-carbon energy using proven economical recycling and fast-neutron technologies. The result in this country alone would currently be the creation of \$74 trillion of reliable electricity on demand without greenhouse gas emissions. It would avoid adding 475 billion tons CO₂ to the atmosphere compared to the use of coal, to mitigate climate change. Worldwide recycling of stored spent nuclear fuel and replenishing with depleted uranium in fast-neutron reactors could avoid emitting over 20 trillion tons CO₂, or over six times the current total atmospheric CO₂ content. As added bonus the long-term radiotoxicity of the used CANDU fuel is effectively eliminated, making a long-term deep geological repository unnecessary. Even the shorter-lived radioisotope fission products become valuable stable atoms and minerals that would fetch \$3 million per ton. Such an alternative is certainly worth pursuing.

1. Introduction

Nuclear power from thermal reactors, including Canada's CANDU reactors, produces prodigious amounts of energy. Curiously, such nuclear power creation is one of the most inefficient processes, converting less than 1% of the potential of nuclear fuel into usable energy.

This seeming paradox is well illustrated by a common analogy. Consider burning only the tinder-like bark off the birch log in your fireplace (Fig. 1). The bark flames up, with the flame providing a momentary satisfying heating glow. But it soon dies to make way for a new firebrand that repeats the procedure, while the old slightly charred unburned log, blackened with charcoal, soot and a few ashes, is discarded.

Surely you would personally quickly learn to build an efficient fire for you to enjoy, a fire that extracts the heat from the entire log, and burns down to a residue of ashes. No char left, no soot, and even the ashes provide fertilizer for the garden.

On a commercial scale operation one could scarcely envision burning only the birch bark tinder from reams

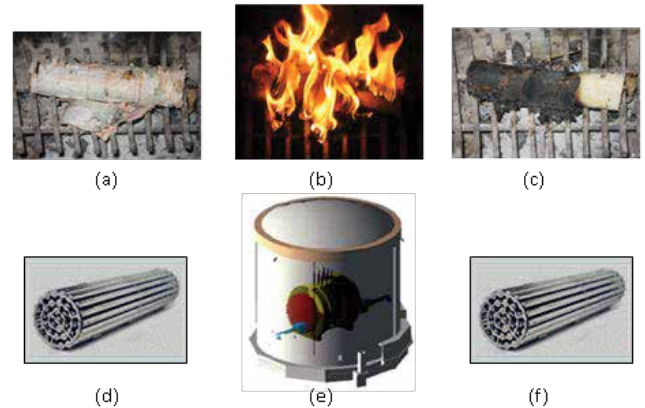


Figure 1. Analogy between birch log in fireplace and uranium fuel in CANDU reactor

(a) A fresh birch log with loose bark tinder, in analogy to fresh uranium fuel bundle with U-235 (d). (b) Lit bark tinder around log burning on grate in fireplace; (e) analogously U-235 in fuel bundle is consumed partially in the pressure tubes of the CANDU reactor (Note: the uranium is split to produce heat, but there is no fire). (c) Charred log, incompletely burned. (f) Spent fuel bundle, mostly U-238, with U-235 reduced from 0.72% to 0.23%, with 0.74% fission products ("ashes") and with 0.4% TRUs (invisibly inside the zirconium cladding of fuel rods)

of logs (Fig. 2) to make electricity. At an industrial scale such stored used charred logs could contaminate the soil and the environment with lyes from the ashes and with surface tars that leach harmful chemical residues including cancer-causing dioxins. Consider then being asked to pay to bury the "contaminated" logs permanently in a cavern built deep underground to sequester them from the biosphere. You would likely soon find a company with a technology that would not only profitably use all components of the logs but that would also detoxify the tars and dioxins in the process.

This scenario in all aspects is effectively the situation of natural uranium fuel use in what I consider the most efficient current thermal reactor design, the CANDU reactors. Once most of the easily lit "nuclear tinder", the small amount of fissile U-235 in the fuel, is consumed in this reactor, a new fuel bundle is requisitioned to replace the old, leaving behind equivalent amounts of fission products ("ashes"), and virtually all of the "nuclear

¹ University of Toronto, Toronto, Ontario, Canada

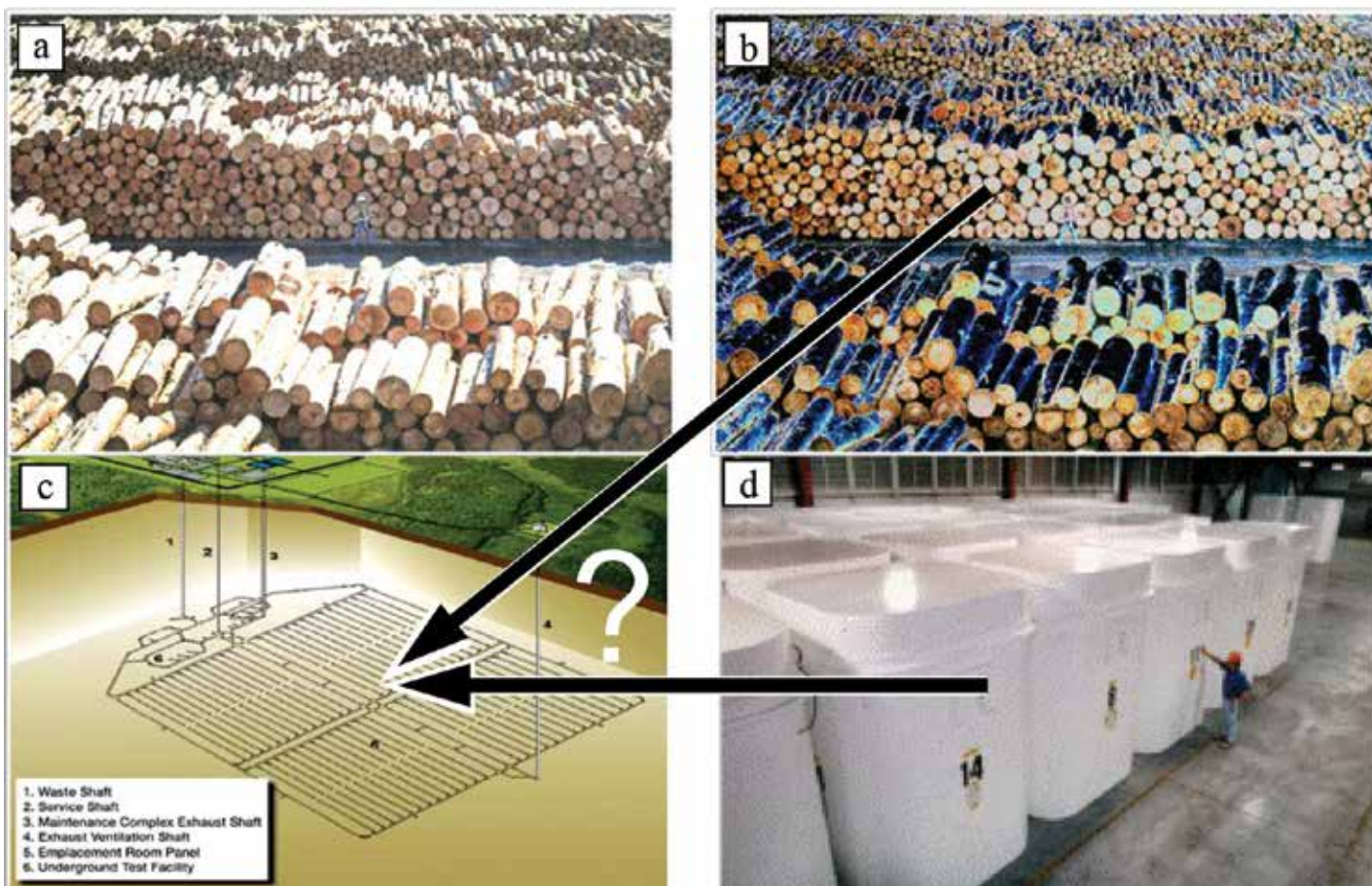


Figure 2. (a) Representative massive pile birch logs. (b) The same pile with the surface bark burned, leaving a charred surface (via image processing). (c) A potential planned deep geological repository. (d) Accumulating used fuel bundles stored dry in concrete castors.

heartwood”, the fertile U-238. A small amount of the U-238 is converted to highly radioactive transuranics (TRUs), atoms heavier than uranium (equivalent to the charred and tarred portion of the birch heartwood with its poisonous and carcinogenic dioxins). Only a small portion of the TRUs, consisting of fissile and fertile atoms, is consumed to create energy.

This process has not changed in principle since the first CANDU reactor was built, with used fuel bundles now amounting to a “pile” of 50,000 tons of over 99% still-usable fuel accumulating in pools and in dry storage (Fig. 2d).

Why does the nuclear industry permit the use of a process that only partially burns the 0.72% fissile U235, the “tinder” in natural uranium, while leaving the 99.68% U238, the massive nuclear heartwood of the fuel, virtually untouched? Worse still, since the consumption of that small amount of uranium leaves only a tiny residue fraction of powerful long-lasting radiotoxins associated with the fuel, why are we asked to pay to bury not only that small fraction but also all of the remaining unused fuel.

Since there is a much better alternative, used fuel cycling through fast-neutron reactors, something is wrong in our nuclear thinking.

2. The Travesty

We proudly point to our CANDU reactors, our nuclear furnaces, as the most efficient uranium fuel consumers among thermal reactors. Heavy-water-cooled CANDU reactors extract about 0.75% of the energy in mined uranium. That is fully half again as much as is obtained in light-water-cooled reactors which manage to extract about 0.5%.

But that is still only an energy yield of 0.5 to 0.75% among all thermal reactors!

One would be hard-pressed to find as inefficient a fuel-to-energy extraction process anywhere in the world. Hydraulic power extracts about 90% of the falling water’s energy. An electric motor converts 80%-90% or more of electrical energy to useful work. A Diesel engine drives 45-55% of the fuel energy into motion, with a gasoline engine, though being only half as efficient, still at 25-30%. Even solar panels convert 10-15% of the sun’s energy falling on them to electricity, with laboratory specimens now at around 40%.

One has to go to nature to find something as inefficient as our thermal reactors: photosynthesis operates at 0.2% to 2% for most crop plants. And even there, the lowly sugar cane manages an 8% efficiency [1].

So why be satisfied with a nuclear energy yield of only 0.5 to 0.75%?

We have accepted that state perhaps because even a yield of nuclear energy this small results in a huge absolute amount of energy. While only 370 tons of the heavy atoms of the current 50,000 tons of stored used CANDU fuel have been split to extract their energy, those 370 tons have produced about 3500 TWh of electricity. At the current mid-time-of-use electricity rate that you and I currently pay in Ontario, those 3500 TWh would fetch \$ 462 billion, although the utilities which produce the power get only about half that.

Since we currently accumulate about 1400 tons of used CANDU fuel per year, the gross revenue yield per year is ~\$ 13 billion. That's \$ 13 billion annually from only about 10 tons of split heavy atoms. The remaining yearly 1390 tons still sit there, idle.

These huge yields seem to blind us from the inefficiency of the process. Worse, although we are more familiar with radiation than most of the population, we seem nevertheless to be transfixed by fear of the fact that within the reactor the used fuel has become highly radiotoxic from the creation of long-lived heavier atoms in the fuel, the transuranics, and from the shorter-lived split atoms, the fission products. As a consequence the intent is to bury all current 50,000 tons of used CANDU fuel summarily and permanently for close to a million years in a deep geological repository (DGR) (Fig. 2c) at a cost of \$ 24 to 40 billion [2, p.163; 3; 4, p.3], with a further 50,000 tons used fuel anticipated by the end of life of the current complement of reactors.

It would be a tragedy in today's era of climate change to bury such a virtually unused resource of non-carbon energy.

We already know how to extract the remaining energy. We also know how to eliminate the long-lived radiotoxicity, and have done so, by recycling the used fuel through fast-neutron reactors. We, internationally, have used the fast-neutron reactor technology since the 1950s [5]. We have developed the associated fuel cycle technology to help consume all of the used (or fresh) uranium fuel and by so doing to eliminate the long-term radiotoxicity of the heavy atoms [5, p. 167ff]. Indeed, the technology was developed with a strong Canadian content.

The travesty is that we have chosen to ignore these proven achievements that point to an effectively inexhaustible unending non-carbon energy future and have insisted instead on a path down a deep hole, down into a DGR. The travesty is that we have acquiesced to paying \$24.4 to \$40.7 billion to build and fill such a DGR [2, p.163; 3; 4, p.3] that will rob us of the potential of \$74 trillion in GHG-free electrical energy from just the current 50,000 tons used CANDU fuel alone. Those 50,000 tons of used fuel, converted into non-carbon heat and electricity, would avoid the emission of 475 billion tons of CO₂ in Canada alone, equivalent to about 15% of all the CO₂

currently in the entire atmosphere. Moreover, the process would permanently eliminate the "million-year" radiotoxicity of the heavy atoms in the fuel, and so avoid the use of an unproven and unprovable DGR. The travesty is that we are turning our backs on that potential.

3. The Wastefulness is Our Choice

This flagrantly poor 0.75% efficiency has been accepted for at least three reasons. First, fresh uranium fuel is still relatively inexpensive, costing Ontario Power Generation (OPG) only 0.54 ¢/kWh currently [6], plus, depending on the calculating assumptions, an additional 0.2-0.4 ¢/kWh for disposal in a DGR [3]. Second, as mentioned above, the nuclear energy extracted from even as little as 0.5% - 0.74% of this non-carbon fuel is huge. It requires only 925 grams of the 125 kg uranium charge in 6.25 CANDU fuel bundles to produce 1 megawatt-year (8.76 million kWh) of non-carbon electricity in a CANDU reactor [2, p.351]. This is enough electricity for 900 households for a whole year [7]. To produce the same amount of electricity for those 900 homes from fossil fuels would take 2,800 tons of coal, or 28 hopper rail cars full of coal [8], and produce emission of 8000 tons of CO₂ [9]. The equivalent use of methane gas would be almost 50% better, but still emit 4700 tons CO₂ [10].

That's a lot of non-carbon energy from very little uranium fuel. But compared to the 925 g, the remaining 124 kg (124,075 g) fuel in the same 6.25 used fuel bundles, if consumed completely by cycling through available fast-neutron reactors [5,11] would produce an additional 134 times the non-carbon electricity, or 134 MW-years worth about \$74 trillion, and avoid the emission of 1,000,000 tons of CO₂ compared to coal.

The 50,000 tons of used fuel replenishing fast-neutron reactors (FNRs) would provide almost 5000 years of nuclear energy for Ontario at our current nuclear power production. In contrast our thermal reactors will run out of economical fissile uranium fuel in Canada in about 40 years [12].

Thirdly, it is often assumed that recycling of used fuel brings with it an increased risk of nuclear weapons proliferation. Yet in over 60 years of commercial nuclear power worldwide no proliferation of nuclear weapons has occurred as a result of commercial fuel cycling. The used fuel from commercial reactors is very poor weapons materials. Moreover, in recycling, as described below, potential weapon materials, elements and isotopes, are not separated. Canada has had the wherewithal to build nuclear weapons since the 1940s and '50s even without fast-neutron reactors and without recycling, but has chosen not to do so. There is no reason to believe that adopting used fuel recycling through FNRs will change Canada's weapons philosophy.

Thus the wastefulness and inefficiency with respect to

uranium fuel use is our choice rather than a technological or even geopolitical necessity. It appears that only our own inertia and our satisfaction with the *status quo* stand in the way of our doing better. Indeed, we are willing to spend \$24 to 41 billion on a questionable million-year burial of Canada's current stored 50,000 ton energy resource of used CANDU fuel when the nuclear industry knows that the long-term heavy-atom radiotoxicity could be eliminated in 50 years or less with recycling in fast-neutron reactors (Fig. 5, below) [13,14].

4. The Root Cause of Uranium Fuel Inefficiency: The Wrong Type of Reactor

The uranium fuel inefficiency is inherent in the nuclear reactors that we now use, be they heavy-water-cooled CANDUs or light-water reactors (LWRs). Both types are “thermal” reactors using neutrons slowed down (“moderated” or “thermalized”) to the same energy or “temperature” as the hydrogen or deuterium atoms in the water used to cool the reactors. Such slow neutrons very efficiently fission, or split, only a small isotopic component of the uranium, the 0.72% U-235 in mined uranium, while splitting the much larger component, the 99.28% U-238, about 50 million times less often, leaving it virtually untouched. A little of the U-238 is converted into heavier elements, some of which can also be consumed. (In the jargon of the field these properties make U-235 “fissile” and U-238 “fertile”.) However, once most of the fissile U-235 is consumed the thermal reactors have to be replenished with fresh fuel.

With the massive power output of the reactors, often on the order of 1000 megawatts, the public and even many workers in the nuclear industry have been blinded to fact that so little of the uranium fuel is actually used up.

4.1 Fuel efficiency using fast neutrons

Clearly we have not accepted this type waste scenario for the utilization of wood. We have perfected efficient woodstoves, as well as learned to lay logs effectively for roaring campfires or economical cooking fires, utilizing every bit of fuel from log to scrap. Even the wood ash was used by our forebears to make soap, and is still used as a source of potassium in our gardens.

Indeed, a similar efficient scenario also exists in the nuclear field: fast-neutron technology with fuel cycling. It was started in the 1950s, fleshed out in depth in the USA in the '80s and '90s, and is now largely forgotten, overlooked, or taught as an historical footnote [5]. Few know that it was a fast-neutron reactor, the EBR-I, that produced the first nuclear-generated electricity in 1951.

The EBR-I successor, the EBR-II fast-neutron reactor (FNR), sodium-cooled to prevent thermalization or moderation of neutrons, was the test-bed from

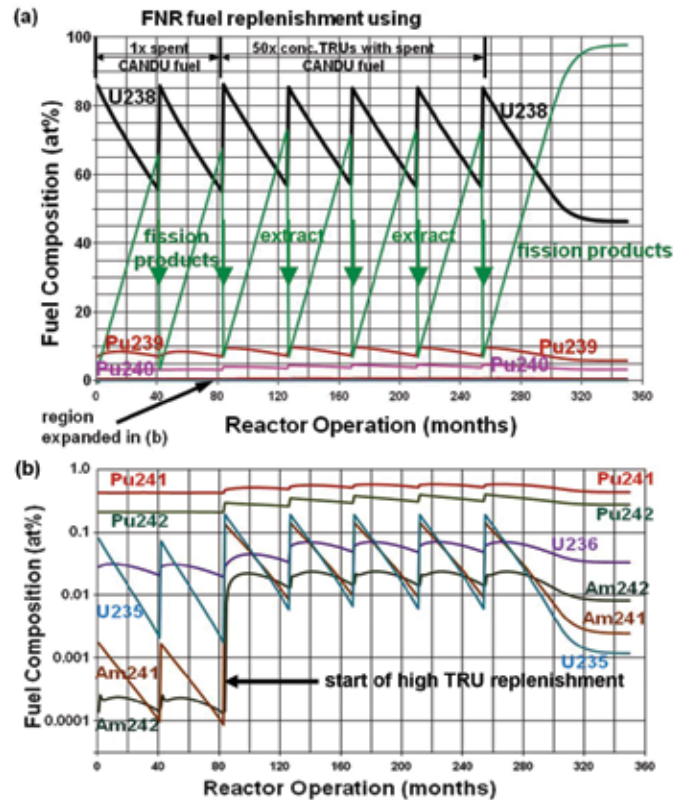


Figure 3. Fast-Neutron Reactor Fuel Behaviour under Replenishment with Two Forms of Used CANDU Fuel

1964 on for increased fuel utilization and for demonstrating passive safety of the technology [5, p.138ff]. It achieved 20% “burn-up” safely in the '80s, compared to 0.74% in CANDUs today. After the decommissioning of the EBR-II in 1994, fuel tests in the French Phenix FNR provided proof that 25% burn-up at least was possible.

These results indicated that not only was the physics of fast neutrons capable of delivering much higher fuel efficiencies than the physics of thermal neutrons, but also that the materials, the steels of the fuel rods and assemblies, were capable of withstanding the increased neutron fluxes at higher energies and at such high levels of fuel utilization.

Even the 25% fuel burn-up found experimentally in FNRs is not the theoretical limit, a limit that would ultimately be determined by neutron absorption in fission products (FPs) that build up in the fuel as more and more heavy atoms are split to extract their energy. That limit is closer to 35% (Fig. 3). To continue fission of heavy atoms beyond this limit it becomes necessary to extract the FPs, i.e. undertake fuel recycling. Such fuel cycling was put in place in conjunction with the EBR-II reactor, recycling about 35,000 fuel pins or five times the load of the reactor [15]. For a 20% fuel utilization achieved in that reactor, five such cycles would utilize the equivalent of 100% of a single reactor load, leaving nothing but FPs.

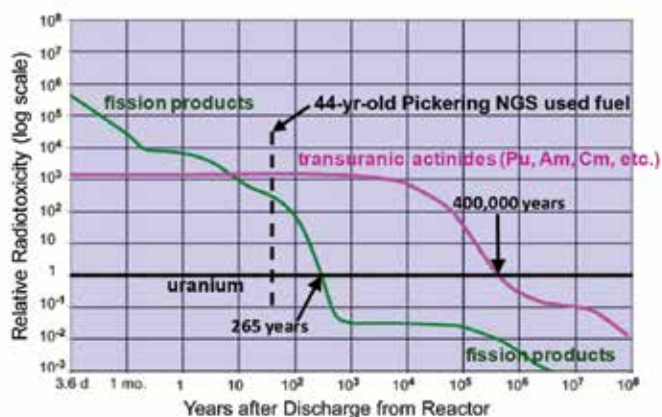


Figure 4. Evolution of Radiotoxicity from Used CANDU Fuel Components Relative to Natural Uranium.

4.2 More Fast-Neutron Advantages

4.2.1. Maintenance of Fissile Content

A particular design advantage of such an FNR is its internal maintenance of the level of fissile atoms required for operation. Thus after the 20% fission products are removed from the fuel at the end of one fuel cycle, the fuel has only to be replenished with any source of fissionable atoms that includes primarily fertile U-238, such as depleted uranium or used CANDU fuel. No additional fissile components are required. At the end of each such cycle, all of the fuel isotopes, uranium and transuranics, reach the same level as at the end of the previous cycle (Fig. 3). This includes the minor actinides such as Am-241 and Am-242, etc., as well as even-numbered major actinide isotopes such as Pu-240 and Pu-242 that accumulate in the used fuel of all thermal reactors. It is this property of FNRs that makes it possible to consume all of the heavy atoms in used CANDU fuel.

As one crucial outcome, as the heavy atoms are fissioned, whether uranium or TRUs, they cease to exist and their long-term radiotoxicity ceases to exist. Short-lived FPs remain (see Section 5).

4.2.2 No Xenon Poisoning: Load-Following

Additionally, one practical operational advantage accrues from the fact that at high energies neutron absorption of any fission product, including Xe-135, is extremely low. At 1 MeV, absorption of Xe-135 is only 0.01 barns versus 2.6 million barns at thermal energies [16]. Therefore “xenon poisoning”, a problem caused by huge absorption of thermal neutrons by the build-up of Xe-135 via decay from I-135 after reactor shut-down, virtually does not exist at high energies (more accurately, the effect is reduced by a factor of 2600). Such reactors can therefore have their power levels changed at will. There would be no delay in powering up or restarting even after longer shut-downs that normally prevent the restart of thermal reactors until xenon absorption has decayed enough, after several 9.2 hr Xe-135 half-lives. Thus load-following of the daily variations in demand of energy could be readily accommodated

by such reactors, opening the possibility of supplanting much GHG-emitting gas-fired electrical generation. (Note added: a referee rightly suggested that “no-xenon-effects” would likely have avoided the Chernobyl disaster. The strong positive feedback on Xe-135 burnout from a power increase in that reactor would not have occurred in an FNR with high energy neutrons; they cause no xenon effects).

5. Elimination of Long-Term Radiotoxicity.

Long-term radiotoxicity is the prime reason cited for discarding used CANDU fuel and to sequester it from the biosphere for the requisite several hundred thousand years (Fig. 4). As pointed out above, using all of the heavy atoms and particularly the transuranic actinides (TRUs) as fuel in FNRs would eliminate the major portion of that future radiotoxicity.

However, since the practical limit of heavy-atom fuel burn-up in FNRs is not 100% but closer to 15-20% [11], the fuel must be recycled, with fission products being removed periodically. In such a process the efficiency of separating fission products cleanly from radiotoxic heavy atoms becomes important, as does the purity and volume of used chemicals after such separation.

5.1 Aqueous Processing: PUREX and Variants

The classical “recycling” procedure is the separation of fissile materials, specifically plutonium, using aqueous chemistry such as PUREX (Plutonium URanium EXtraction) or its modifications. Facilities used at La Hague in France, and Sellafield in the UK, for example, are huge, leave large volumes of radioactive liquids, and are expensive - the still unfinished Rokkasho (Japan) facility already cost \$25 billion [17]. Moreover, with the focus on recovering and cycling only fissile isotopes, the amounts of radiotoxic materials are only minimally reduced.

5.1.1 Aqueous Processing: Two Other Drawbacks

Even discounting the expense, aqueous processing results in products that are particularly sensitive to weapons proliferation. PUREX was intentionally designed by the military to produce pure weapons-grade plutonium. However, even derivatives of PUREX, such as COEX, UREX, GANEX, etc., provide products that are relatively pure mixtures of alpha-emitting transuranics and uranium which are amenable to being easily handled directly without shielding, and therefore open to being readily diverted for further nefarious purification.

In addition, any accidental leakage of the aqueous radioactive solutes and solvents might result in seepage into ground water before a clean-up could be instituted.

5.2 Non-Aqueous Recycling: Pyroprocessing

A better approach, specifically designed for recycling used metal fuel from FNRs, is non-aqueous pyrometallurgical electrolytic separation, or “pyroprocessing”, developed at the Argonne National Laboratories, and still operating [5, p.181]. The cost of a full sized facility is estimated at \$ 0.1 billion [5, p.291]. This procedure produces three fractions from the fuel: 1) pure uranium, 2) a mix of all TRUs with a few fission products (FPs) as impurities plus any remaining uranium, and fraction 3): all other FPs. There is no separation of plutonium, or any other TRU. Fraction 1) and 2) contain heavy atoms that are recycled into the FNRs. Fraction 3), the FPs, are put into medium-long storage to decay further for a maximum of 300 years (Fig. 4), although most become stable after a few decades. Useful stable or radioactive isotopes can be extracted, and many are already for sale [18]. Zirconium, even long-lived radioactive Zr-93, can be recycled into FNR metal fuel, while activated iron casings are compacted and treated like FPs, for decay. Molten salt electrolytes are recycled, leaving effectively no process wastes for disposal.

Any spillage of the hot molten salt solutions would result in almost immediate solidification to make clean-up relatively easy.

Still, this non-aqueous separation process is not perfect. Laidler et al. [19] indicate that pyro-processing achieves a separation of better than 99.9% of the actinides from the fission products. This does not result in a complete elimination of the long-term TRU radiotoxicity in fraction 3), but the degree of separation would lower the toxicity of the TRUs over 1000-fold to the level of the original natural uranium or below (cf. Fig. 4).

This TRU level among the fission products may be considered sufficient to obviate the need for a long-term DGR. If not, one has effectively 300 years to search for a better separation method before those remaining TRUs would become the dominant radiotoxic component of fraction 3).

Furthermore, the less than perfect separation of FPs from the TRUs in fraction 2 makes clandestine diversion for nefarious purposes particularly difficult. This fraction, still being highly radioactive, has to be shielded and processed remotely to make new FNR fuel. This necessity imparts a very high degree of proliferation resistance to the pyroprocess..

5.3 Accelerated Detoxification of TRUs

One additional advantage of the non-aqueous pyroprocess is its ready potential to accelerate the long-term detoxification of existing used nuclear fuel. Since one fraction, fraction 2), contains the long-lived TRUs, this fraction can be recycled into FNRs preferentially as fuel to eliminate the TRUs without a major

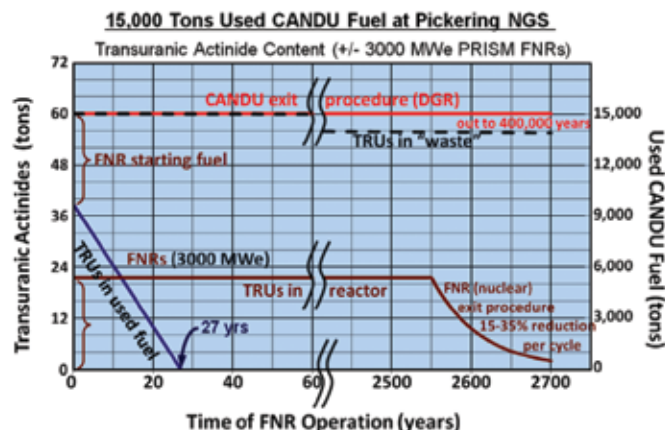


Figure 5. Accelerated consumption of long-lived transuranic actinides in 15,000 tons used CANDU fuel with recycling through 10 PRISM-like 300 MW fast-neutron reactors.

effect on the operation of the reactors. This is demonstrated in Fig.3, which from month 82 on depicts the replenishment of FNR fuel using a 50-fold increase in the use of pyroprocess fraction 2), i.e. the mixture of all TRUs plus some uranium (see also [13]).

This approach can be remarkably effective and quick. It can be calculated that with such a procedure it would take only ~27 years to eliminate the small (0.4%) long-term radiotoxic TRU component from the 15,000 tons of used CANDU fuel that would be stored at the Pickering nuclear reactors after their shutdown in 2020 (Fig. 5) [13]. Part of those TRUs would become the required constant “in-reactor” fissile fuel component of the FNRs until their decommissioning.

After the 27 years to eliminate the “out-of-reactor” TRUs in the stored used CANDU fuel, the FNR fuel could be replenished for centuries with stored pure depleted uranium from fraction 1) since FNRs can conserve their fissile fuel content. The requirement would be a fleet of FNRs equal in output to the current 3000 MW Pickering plant along with a fuel cycling complex that included a 50 ton/year pyroprocessing facility and a feeder pre-treatment plant to extract 90% pure uranium from the stored used CANDU fuel. Both components of the fuel cycling complex would be about 10-fold smaller than the existing PUREX plants mentioned in Section 5.1 above.

If a better fuel source is found in future, then at any time after the use and consumption of TRUs from the stored spent CANDU fuel, from 27 years in the Pickering case to over 2500 years (Fig. 5), the best exit strategy for the FNRs would be to diminish the number of reactors at each fuel cycle in proportion to the fuel consumed in the reactors in that cycle, e.g. ~15% for PRISM-like FNRs. In this way the eventual amounts of long-term TRUs left within the reactors are driven to a minimum of less than the fuel charge of the final single reactor.

6. Long-Lived Fission Products

As is evident in Fig. 4, beyond 300 years fission products contain isotopes that are also long-lived. Even though their total radiotoxicity is well below that of the uranium from which they were formed, concern exists about specific isotopes that are biologically important and might require special handling. The treatment and elimination of only 7 isotopes, either early or perhaps more easily after 300 years, would bring the toxicity level to about 1 million times lower than the toxicity of natural uranium. Only iodine-129 ($T_{1/2} = 17 \text{ M y}$) with a toxicity level 40,000 less than its natural uranium parent, will be mentioned, since it can accumulate in human thyroid tissue.

The pyroprocess of fuel recycling runs at about 500°C. At this temperature iodine is volatile and consequently I-129 is captured as a vapour in cold traps. With a neutron absorption of 30 barns it can be relatively easily transmuted to I-130 in a thermal reactor. I-130 decays with a half-life of 12.3 h to stable Xenon-130. Thus a 17 M-year concern is changed to a 12.3-hour non-problem.

The other isotopes require different approaches for isolation and transmutation; or they can be re-used, such as zirconium, including Zr-93, as alloying element in FNR metal fuel (section 5.2).

7. Cost of Recycling

Till and Chang have estimated the cost of recycling FNR fuel at 0.44 ¢/kWh, including capital, operation and storage of fission products. Bushby at the Canadian Nuclear Laboratory estimates a mid-price of 0.66 ¢/kWh for recycling alone [5,p.292; 20]. This suggests that FNR fuel cycling is similar in cost to purchase by OPG of fresh fuel plus its cost for disposal (0.5 + 0.2 ¢/kWh [21]).

8. Conclusion

In today's climate of reduce, re-use, and re-cycle, along with a strong worldwide emphasis on increasing the use of carbon-free energy, it seems utterly wrong to focus on the permanent disposal of Canada's used CANDU fuel which can currently provide about \$74 trillion of non-carbon electrical energy over centuries. Its use can avoid the emission of about 275 billion tons of CO₂ to the atmosphere compared to the use of natural methane gas (470 billion for coal). That fuel resource requires no mining, and is already stored at reactor sites ready to be exploited.

If there were no other choice, and no further energy could be easily extracted by known means, one could condone burial of the used fuel, since it is highly radioactive and will be for millennia. But we, the nuclear establishment, know how to eliminate the long-term

radiotoxicity by recycling the fuel through energy producing FNRs; and have done so. We therefore have that choice. Neutron physics created the radioactive material, and neutron physics has the ability to destroy it. It has been proven and has been accomplished safely – with the help of Canadians [5].

Surely this is the path we should follow. It is a path on which we can lead the world. Now.

10. References

- [1] Energy Efficiencies. http://www.mpoweruk.com/energy_efficiency.htm#comparison
- [2] Choosing a Way Forward: The Future Management of Canada's Used Nuclear Fuel. Final Study. NWMO, 22 St. Clair Avenue East, Sixth Floor, Toronto, Ontario, M4T 2S3 Canada. www.nwmo.ca/studyreport/?action=download-file&id=341
- [3] "Moving Forward Together", Triennial Report 2008 to 2010. NWMO http://www.nwmo.ca/uploads_managed/MediaFiles/1721_triennialreport2008to2010.pdf
- [4] M. Hung, "Financial Implications of Used Fuel", APM-REP-03780-0001 December 2008 http://www.nwmo.ca/uploads_managed/MediaFiles/358FinancialImplicationsofUsedFuelVolumeVariationinLongTermManagement2008Update.pdf
- [5] C.E. Till and Y.I. Chang. "Plentiful Energy", publ. CreateSpace (Amazon), 2011. Accessible on-line: <http://www.thesciencecouncil.com/pdfs/PlentifulEnergy.pdf>
- [6] Ontario Power Generation Annual Report 2014: <http://www.opg.com/news-and-media/Reports/2014AnnualReport.pdf>
- [7] Your home electricity bill: A study on the costs in Ontario http://environmentaldefence.ca/sites/default/files/report_files/Your%20Home%20Electricity%20Bill%20-%20Study.pdf
- [8] Coal Power. <http://pcmstechnology7.org/TSA/coal.html>
- [9] B.D. Hong and E. R. Slatick. Carbon Dioxide Emission Factors for Coal. U.S. Energy Inf. Admin. http://www.eia.gov/coal/production/quarterly/co2_article/co2.html
- [10] Electricity in Ontario. <http://media.cns-snc.ca/ontarioelectricity/ontarioelectricity.html>
- [11] Triplett, Brian S., Eric P. Loewen, and Brett J. Dooies. "PRISM: a competitive small modular sodium-cooled reactor". Nuclear Technology Vol. 178, 186-200, 2012.
- [12] <http://www.world-nuclear.org/info/Country-Profiles/Countries-A-F/Canada-Uranium/>
- [13] P. Ottensmeyer, "Productive Elimination of Nuclear Waste (PENW): A Complementary Boon for CANDUs and the Canadian Nuclear Industry" Proceedings of the 35th Annual Conference of the Canadian Nuclear Society, Saint John, NB, 2015 May 31 – June 03.
- [14] http://ontarioenergyreport.ca/pdfs/MOE%20-%20Feasibility%20Study_Used%20Fuel%20Recycling%20-%20June%202016.pdf
- [15] Hofman, G.L., L.C. Walters, and T.H. Bauer, "Metallic fast reactor fuels," Progress in Nuclear Energy. Vol. 31, 1997. p. 83-110.
- [16] National Nuclear Data Center, BNL. <http://www.nndc.bnl.gov/sigma/getPlot.jsp?evalid=15174&mf=3&mt=102&nsb=10>
- [17] <http://www.bloomberg.com/news/articles/2016-01-04/japan-s-25-billion-nuclear-recycling-quest-enters-28th-year>
- [18] Advanced Materials Technologies Ltd. <http://www.iso-tope-amt.com/website/site/index.asp>
- [19] J.J. Laidler, J.E. Battles, W.E. Miller, J.P. Ackerman, E.L. Carls, "Development of pyroprocessing technology", Progress in Nucl. Engineering, Vol. 31, 1997, pp.131-140.
- [20] S. Bushby. COG Workshop on Used CANDU Fuel, Toronto, Jan. 21/22, 2015.
- [21] <http://www.opg.com/news-and-media/Reports/2014AnnualReport.pdf>

GENERALnews

(Compiled by Colin Hunt from open sources)

SNC-Lavalin Agrees to Build New CANDU Reactors in China

SNC-Lavalin has signed a deal with two Chinese companies on a joint venture that will see Canadian CANDU reactor technology used to build nuclear plants in China and possibly elsewhere.

The Montreal-based engineering company said in a release September 22 that it will partner with China National Nuclear Corp. and Shanghai Electric Group Co. Ltd. to place two “design centres” – one in Canada and another in China – which will develop at least two nuclear power plants in China using the most advanced version of the CANDU reactor technology that SNC bought from the Canadian government for \$15 million in 2011.

“This is a game changer in the nuclear industry, and a great endorsement of our expertise and ... nuclear technology from the largest nuclear market in the world,” SNC-Lavalin Power’s president Sandy Taylor said.

The Advanced Fuel CANDU Reactor (AFCR) will use recycled uranium fuel from existing reactors to produce power. Each AFCR can use the fuel of four light-water reactors to generate up to 6 million megawatt-hours of electricity without needing any new natural uranium fuel, SNC said. Roughly speaking, that’s enough to power four million Chinese households every year.

OSART Mission Arrives at Pickering

A team of nuclear experts led by the International Atomic Energy Agency (IAEA) arrived on September 19 at OPG’s Pickering Nuclear Station to conduct a standard Operational Safety Review Team (OSART) mission.

“This is an important international review for OPG and Canada,” said OPG’s Nuclear President and Chief Nuclear Officer Glenn Jager. “This is an opportunity for us to showcase our commitment to excellence and safety, and to share best practices with these international experts.”

Pickering Nuclear was put forward for this review in 2014 by the Canadian Nuclear Safety Commission,

Canada’s independent nuclear regulator and active participant in the international nuclear community. The OSART program has been providing member countries the opportunity to share knowledge and to support continuous improvements to their operations since 1982. Best practices identified through these reviews are shared with other nuclear operators through the IAEA.

In the 2015 Nuclear Safety Report, OPG’s Pickering and Darlington nuclear stations received the highest possible safety rating of “fully satisfactory” and for Darlington, it’s the seventh year in a row the station has achieved this rating. Combined, the plants provide about 30 per cent of the electricity used in Ontario.

Darlington Refurbishment starts this Fall

Years of preparation, planning and practice has ensured the Darlington Refurbishment will begin mid-October. Today, OPG released the latest in a series of performance reports that have tracked the company’s efforts for the past two years.

“I’m pleased to report it’s all systems go for Canada’s largest clean energy project,” said Dietmar Reiner, SVP Nuclear Projects. “Come October, we’ll shut down Unit 2, the first of four nuclear units to be refurbished, and begin removing, replacing and overhauling critical components.”

Highlights from the semi-annual performance report include:

- Cost performance has been excellent and has improved since the last reporting period;
- Safety performance has been excellent – the team has worked 2,372 days without a lost-time accident;
- OPG remains within the \$12.8 billion project estimate;
- All necessary materials have been delivered;
- Worker training at the state-of-the-art reactor mock-up continues;
- The detailed execution plan has been finalized.

“The \$12.8 billion Darlington Refurbishment will generate \$14.9 billion in economic benefits for Ontario and create an average 8,800 jobs per year,” added Reiner. “Once refurbished, Darlington will continue providing safe, reliable energy that is virtually free of

greenhouse gas emissions for the next 30 years. This vital base load power will also cost less than other alternatives considered.”

Darlington Hosts World University

Darlington Nuclear is welcomed students from the World Nuclear University Summer Institute (WNU) on July 13.

“We’re excited to open our doors and very proud WNU will be coming to visit Darlington,” said Brian Duncan, Darlington’s Senior Vice President. “These are the future leaders of the nuclear industry. It’s crucial they share experiences, learn from industry experts and see how plants around the world operate,” Duncan added.

WNU is a global partnership committed to international education and leadership development by bringing together some of the best young minds in the nuclear industry. Each summer, WNU sponsors an intensive six week program. During the course the participants learn from experts in such disciplines as sustainable development, innovations in nuclear technology, safety and operations. Participants come from Argentina, Armenia, Bangladesh, Spain, Ireland, South Africa, Brazil, Japan, France, Russia, USA and China. This is the second time Canada has hosted the event, which is sponsored by OPG, AECL, Cameco Corporation, Canadian Nuclear Society and Natural Resources Canada.

Bruce Power Receives Highest Rating from CNSC



Bruce B

Bruce Power has received its best-ever report card from the Canadian Nuclear Safety Commission (CNSC), the country’s independent regulator of nuclear facilities.

Both Bruce A and B received an overall ‘Fully Satisfactory’ mark for the CNSC’s Integrated Plant Ratings, which the regulator has compared to an ‘A+’ in past media reports. Both stations were also deemed Fully Satisfactory for Operating Performance, Conventional Health and Safety, Waste Management and Security. The other 10 areas rated by the CNSC were deemed ‘Satisfactory,’ which is equivalent to an ‘A.’

“This is the first year both of our stations have been deemed to be Fully Satisfactory, now that Bruce A has joined Bruce B with this prestigious ranking,” said Len Clewett, Bruce Power’s Chief Nuclear Officer. “Since the Units 1 and 2 refurbishment project was completed in 2012, the staff have worked extremely hard to improve the reliability of Bruce A, while always maintaining our Number 1 value of Safety First. We are seeing the fruits of their labour today, as we celebrate this achievement across the Bruce Power team.”

Bruce Power Prepares for Major Component Replacement

Bruce Power has taken an important step toward its refurbishment preparations by opening the Centre for Project Excellence on the Bruce site.

The centre will be dedicated to the company’s extensive planning activities to prepare for the successful execution of the first refurbishment, which begins in 2020.



Mike Rencheck, Jeff Phelps, Ian Kennedy open Centre.

“A key priority at Bruce Power is project excellence and that’s why preparing for the successful execution of our refurbishment program, which will begin in 2020, is an important focus for our organization,” said Mike Rencheck, Bruce Power’s President and CEO. “The opening of the Centre for Project Excellence is another important milestone as we prepare for the successful execution of future refurbishments that are important to our site, surrounding communities and

the Province of Ontario.”

The Centre for Project Excellence is a 60,000 sq. ft. facility of combined office and warehouse space that will house the project team for the refurbishment preparations.

Low Emissions from Canadian Uranium Mining



Gordon Sparks, David Parker, Cameron McNaughton

Uranium mining and milling contribute only a small amount to nuclear energy’s already low greenhouse gas emissions, the first comprehensive life cycle assessment of greenhouse gas emissions produced from Canadian uranium mining operations has found.

The work by David Parker, Cameron McNaughton and Gordon Sparks has been published in *Environmental Science and Technology*, an online peer-reviewed journal.

The life cycle assessment involved gathering information on all the greenhouse gases emitted by everything used in the mining and milling of uranium at three Saskatchewan sites, including fuel used in heavy machinery and to power facilities, the concrete and steel used in construction, emissions from flying workers to and from the mine sites and even took into account emissions from company head offices.

The researchers also visited mine and mill sites and worked alongside uranium producers Areva and Cameco. They found the dominant sources of emissions to be the electricity consumed and the propane used for heating at the sites in northern Saskatchewan.

They found that uranium mining and milling contributes about 1 gram of CO₂ equivalent per kilowatt-hour of electricity generated from the uranium. “Saskatchewan has the highest grade uranium in the world, and the emissions from uranium mining in Canada are very, very low when compared to extracting fossil fuels,” Parker, a graduate student at the

University of Saskatchewan College of Engineering, said.

“We hypothesized that the emissions from the mining and milling of uranium would be low, and we’re finding that’s the case - and they’re even lower than we had expected at the start,” McNaughton, an environmental engineer at Saskatoon-based Golder Associates, said in a video explaining the work.

2014 figures from the United Nations Intergovernmental Panel on Climate Change cite a mid-range value of 12 grams CO₂ equivalent per kilowatt hour for nuclear power, which is similar to wind power, while coal produces over 800 grams per kilowatt hour and natural gas about 500 grams.

“Many people think that the mining and milling of uranium is a hidden source of greenhouse gas emissions related to nuclear power - that it’s the dirty end of the stick”, McNaughton said. “This study, which is the most rigorous done to date, showed that the mining and milling of uranium produces only a small amount of emissions.”

The work was funded through a grant from the University of Saskatchewan’s Fedoruk Centre, which was established in 2011 as the Canadian Centre for Nuclear Innovation. The researchers hope to expand their work to look at the impact of ore grade and different mining processes on emissions as well as broadening it to consider other environmental impacts beyond greenhouse gases.

UK government Gives Approval for Hinkley Point C



Hinkley Point C

The UK government announced September 15 its approval for the construction of two EPR reactors at the Hinkley Point C nuclear power plant in Somerset after reaching a new agreement in principle with EDF. However, it has imposed certain conditions for foreign investment in future British nuclear power plant projects.

Hinkley Point C received a long-awaited and positive

final investment decision (FID) from the EDF board on 28 July, only for the UK government to immediately postpone signing its supporting agreements. Prime Minister Theresa May said a review of the deal would be carried out before the government commits its support. Under a deal agreed with EDF Energy last October, China General Nuclear will take a 33.5% stake in the project. In addition, the two companies plan to develop projects to build new plants at Sizewell in Suffolk and Bradwell in Essex, the latter using Chinese reactor technology.

The government announced it has signed a revised agreement in principle with EDF for the project. While the agreed contract for difference (CfD) - the guaranteed price for electricity generated by Hinkley Point C - still stands, the government has imposed what it calls "significant new safeguards for future foreign investment in critical infrastructure".

Heysham Sets 940-Day Continuous Operation Record

Unit 2 of the UK's Heysham II nuclear power plant was taken offline today for a scheduled maintenance



Control room, Heysham Unit 2

and inspection outage, setting a new world record for the uninterrupted operation of a commercial power reactor. The achievement was announced by Vincent de Rivaz, CEO of EDF Energy, at the World Nuclear Association's Annual Symposium in London.

The Advanced Gas-cooled Reactor (AGR) - also referred to as Heysham 2 unit 8 - operated non-stop since 18 February 2014. The Heysham I and II plants feature a total of four AGR units.

Unit 2 of Heysham II had generated more than 14 TWh of electricity and avoided the emission of over 7 million tonnes of carbon dioxide over the 940-day run.

Earlier this year EDF Energy announced new extended scheduled closure dates for four of its nuclear power stations, with Heysham 2 now scheduled to operate until 2030, an extension of seven years.

Start Engineering Your Career

You're not just looking for a job - you want to build the future. Top employers are looking for people with your qualifications and drive on EngineeringCareers.ca.

Affiliated with the Engineering Institute of Canada, EngineeringCareers.ca is the country's largest job site dedicated just to engineers. Create your free account to connect with great opportunities across numerous engineering disciplines.

- Post your resume online
- Find exciting jobs
- Be the first to hear about new opportunities by having them emailed right to your inbox as soon as they're posted.

Create your account on EngineeringCareers.ca.
Your future starts today.



The Engineering Institute of Canada

Powered by WORKSPOLIS
Niche Network

Lancez votre carrière en génie

Vous n'êtes pas simplement à la recherche d'un emploi - vous voulez bâtir votre avenir. Les meilleurs employeurs au pays sont à la recherche de candidats ambitieux et compétents sur EngineeringCareers.ca.

Affilié à l'Institut canadien des ingénieurs, EngineeringCareers.ca est le plus important site d'emploi en ingénierie au pays. Créez gratuitement votre compte et trouvez d'excellentes occasions d'emploi dans une grande variété de disciplines liées à l'ingénierie.

- Affichez votre CV en ligne
- Trouvez des emplois stimulants
- Sautiez sur les dernières occasions d'emploi en étant avisé par courriel dès qu'elles sont affichées.

Créez votre compte sur EngineeringCareers.ca.
Votre avenir commence maintenant.



L'Institut canadien des ingénieurs

Developed by
Réseau CiblÉ
WORKSPOLIS

Meet The CNS President



Peter was born in January 1956 in a town called Uromi in Esanland of Nigeria. He is the fourth of four surviving children of his parents. His elder brother and two sisters currently live in Nigeria. He grew up in Benin City, Nigeria where he had his elementary and secondary school education. As a young boy growing up, he was interested in leadership and group activities. He became a member of the Boy Scout Movement while still in elementary school.

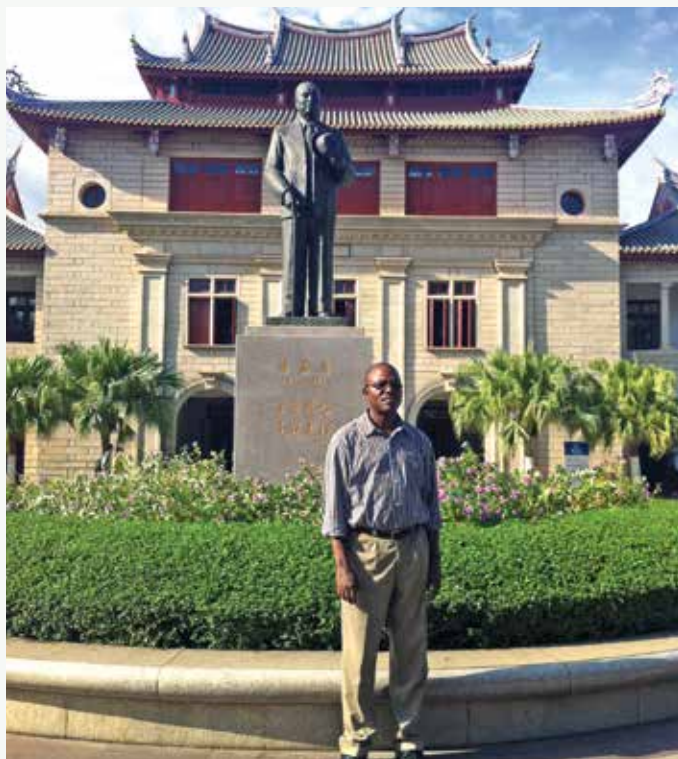


Peter as guest speaker.

Education

Peter attended the University of Lagos Nigeria and obtained B.Sc (Honours) in Chemistry in 1981. On completing the mandatory one year National Service in 1982, he went back to school to study engineering. He completed his Graduate Diploma in Chemical Engineering from the University of Benin in 1984 and continued at the University of Ife, Nigeria, where he obtained his Master's Degree in Chemical Engineering in 1986 with specialization in Separation Processes.

In 1994, Peter started PhD program in Chemical Engineering at the University of Benin. In 1998, he moved to United States of America, and enrolled at the Illinois Institute of Technology, Chicago Illinois



Peter in Xiamen, China.

where he obtained a Master's Degree specializing in Electrochemistry and Fuel Cells. Peter continued his PhD studies at the University of Benin, and by the summer of 2005, he completed the requirements for the award of the doctorate degree and was awarded his PhD degree in Chemical Engineering. His Thesis was on the Study of Kinetics of White Oils Production.

In 2009 Peter completed Project Management courses at Centennial College, Toronto, after which he took the Project Management Institute (PMI) certification examination as a Project Management Professional (PMP)

Work

Peter had a varied work life which included several teaching engagements from high school mathematics in 1976 through to college. On graduating from the university in 1981, he went for the mandatory National Service – a program of the Federal Government of Nigerian for University and College graduates. Peter's

National Service was deployment to a State University as Graduate Assistant in Chemistry.

In 1987, Peter was employed to teach Chemical Engineering courses at the Federal Polytechnic, Bida Nigeria. He was there till October 1988 when he gained employment at the Federal University of Technology, Minna as Lecturer in Chemical Engineering. He spent ten years at the University and held various positions of increasing responsibilities including a member of the University Senate. Peter also had brief spells teaching at University and colleges respectively in USA and Toronto. Between 2001 and 2002, he was a Teaching Assistant at Illinois Institute of Technology (IIT), Chicago. In 2003, he was a Part-Time Contract Professor of Analytical Chemistry at Humber College, Toronto; while in 2010, he was Part-Time Contract Professor of Engineering Mathematics at Sheridan College, Brampton.

For a few years Peter worked in the pharmaceutical industry as a Stability Analyst of marketed drugs. The experience gained working in this regulated industry will become useful in his transition to the nuclear industry. In February 2011, Peter was employed by Tyne Engineering as a Process Engineer. His employment included working as Project Manager when assigned.

Tyne Engineering has over 30 years of experience in the design and manufacture of complex engineering systems for nuclear and tritium-handling industries. In the nearly six years that Peter has been with Tyne Engineering, he has risen steadily in position with increasing responsibilities. His positions have included Manager of Projects, Head of Projects Department, and Manager of Process Systems Division. Currently, Peter heads the Business Services Division of the Company. In this position, he oversees Company Finances, Training and Auditing, Sales and Marketing, Business Administration, and Project Services.

Volunteering

Peter grew up with the notion that in all aspects of life, giving of self is the key to success. He joined the Boy Scout in elementary school, pursued this through high school. In University, he volunteered with the Nigerian Red Cross and later became the Commandant of the University Unit of the Red Cross. This provided a vehicle for Peter to serve the University and the surrounding community.

In 1987 when Rotary was introduced to the Federal Polytechnic Bida where Peter lived and worked, he was inducted as a member. As a Rotarian, he served his Club in various capacities including organizing the Rotary Youths (Intaractors and Rotaractors), and being part of the Rotary PolioPlus Program. As a Rotarian, Peter was twice bestowed the prize of the “Most Informed Rotarian” of District 9130 contest. In 1998, he became the President of his Local Rotary Club.

Peter has been very active in his community. In



Peter at Grand Park in Chicago.

2004, Peter together with a number of other Nigerian-Canadians, organized and inaugurated the Toronto Chapter of the Nigerians in Diaspora Organization in the Americas (NIDO Americas). NIDO is a worldwide not-for-profit organization of Nigerian Professionals. Peter served as the President of the Toronto Chapter of this organization from 2010 – 2013.

Peter's community involvement resulted in him leading the Support Committee of the Royal Canadian Army Cadet Corps of Brampton from 2008 to 2010. He was also a Soccer Coach with the Brampton Youth Soccer Club for Under 12 and Under 13 youths. Peter continues to serve as a Director in a number of Community Boards including Nigerian Canadian Association (NCA), African Canadian Social Development Council (ACSDC), Uzimma Women of Canada.

Peter joined the Canadian Nuclear Society in 2011. His interest in the Society heightened after attending the 2012 Annual Conference in Saskatoon. Though he had applied (unsuccessfully) to participate on the 2013 Annual Conference Organizing Committee, the opportunity to serve came through a call for nominations on the Society's Council. Peter became a Council member in 2013. After one year as a Council member, his name was put forward for the position of the Society's 2nd Vice President. Unknown to him, another member agreed to assume that position. Hence for the first and only time to date, a formal balloting process was held for that position. As the saying goes, “the rest is history”. In his speech at that AGM, Peter promised to work following the Rotary's “Four Way Test”, a promise he reiterated in his acceptance speech as the CNS President at the 2016 AGM.

The Four Way Test of the Things We Think, Say or Do:

1. *Is it the Truth*
2. *Is it Fair to All Concerned*
3. *Will it build Goodwill and Better Friendship*
4. *Will it be Beneficial to All Concerned*

Peter loves travelling. In the near future, he plans to visit Australia and somewhere in the Antarctica to complete being in the 7 continents of the World.

A Modernized Strategic Direction for the CNS

by JACQUES PLOURDE, Chair of Strategic Planning Sub-Committee

Starting with the Officers' Seminar in the Fall of 2015, the Extended Council of the CNS initiated the development of a modernized Strategic Plan to guide its path for the next 5 years. It was time; the CNS had been operating to a strategic direction established back in 2010.

While stepping through the Strategic Planning process, the team's first goal was to understand clearly what the CNS has to be about in this ever-changing nuclear landscape, so that this can be communicated more effectively to our stakeholders.

The result becomes our Strategic Plan preamble, setting the tone for the next five years:

Mission

A mission statement is an overarching, timeless expression of our purpose and aspiration; a declaration of why we exist as an organization.

Support and promote nuclear Science, Engineering & Technology, and related fields, by:

1. Acting as a forum for the exchange of ideas and information.
2. Advancing education, knowledge and understanding.
3. Enhancing and maintaining the professional and technical capabilities of those involved in the field, particularly in the Canadian context.

Vision

The vision is a short, concise statement of the future answers to the question of what the CNS will look like in 5 years.

The CNS is the organization of choice in Canada for the nuclear Science, Engineering & Technology community and its stakeholders¹ seeking accurate information about nuclear related disciplines and issues.

¹ Stakeholders include the general public, labour unions, government, educational institutions, the private sector, and media representatives.

Values

Value statements are enduring, passionate and distinctive core beliefs; guiding principles that never change and are part of our strategic foundation.

The CNS:

- Constantly strives to provide trustworthy, objective,

accurate and easy-to-understand information that conveys an appreciation of nuclear Science, Engineering & Technology concepts, and their benefits to society.

- Respects and supports its members through professional development, training, education and the open exchange of ideas and information.
- Endeavours to determine, employ, and disseminate the best available scientific information and methodologies.
- Seeks no net gain or financial reward for its work and activities.
- Conducts itself at all times in an open, ethical, and professional manner.
- Is apolitical and objective in its work and activities.

Competitive Advantage

In a competitive environment, what we're best at; how we show added value.

The CNS:

- Has an excellent track record at organizing major national and international professional events focused on sharing knowledge and experience, and on networking.
- Comprises a membership with considerable depth and breadth of knowledge and experience.
- Covers all areas of nuclear Science, Engineering & Technology, and related disciplines.
- Is open to all who share its mission and values.
- Is volunteer-based, offering nuclear science, engineering and technology professionals, as well as interested members in other disciplines, significant personal development and information sharing opportunities.
- Works for the benefit of its members and the community-at-large.
- Is not-for-profit.
- Is independent.
- Maintains working links with national and international engineering and scientific organizations, both nuclear and non-nuclear.
- Benefits from inter-Society opportunities for cooperation.

Keeping the above in mind, Extended Council continued its journey by working out the strategic objectives that would best help the CNS achieve its Vision. A total of 7 face-to-face and telephone meetings were held in 2015-2016 where team members were able to provide their input and discuss options with their peers.

Long-Term Strategic Objectives

What to focus on in the next 5 years to achieve our vision.

In the process, many strategies were put forward to support these objectives. They include:

- Strengthening our communication paths to our Stakeholders
- Reviving our local Branch program
- Holding face-to-face meetings with our Stakeholders to re-acquaint them with the CNS
- Implementing a robust succession plan for CNS key roles

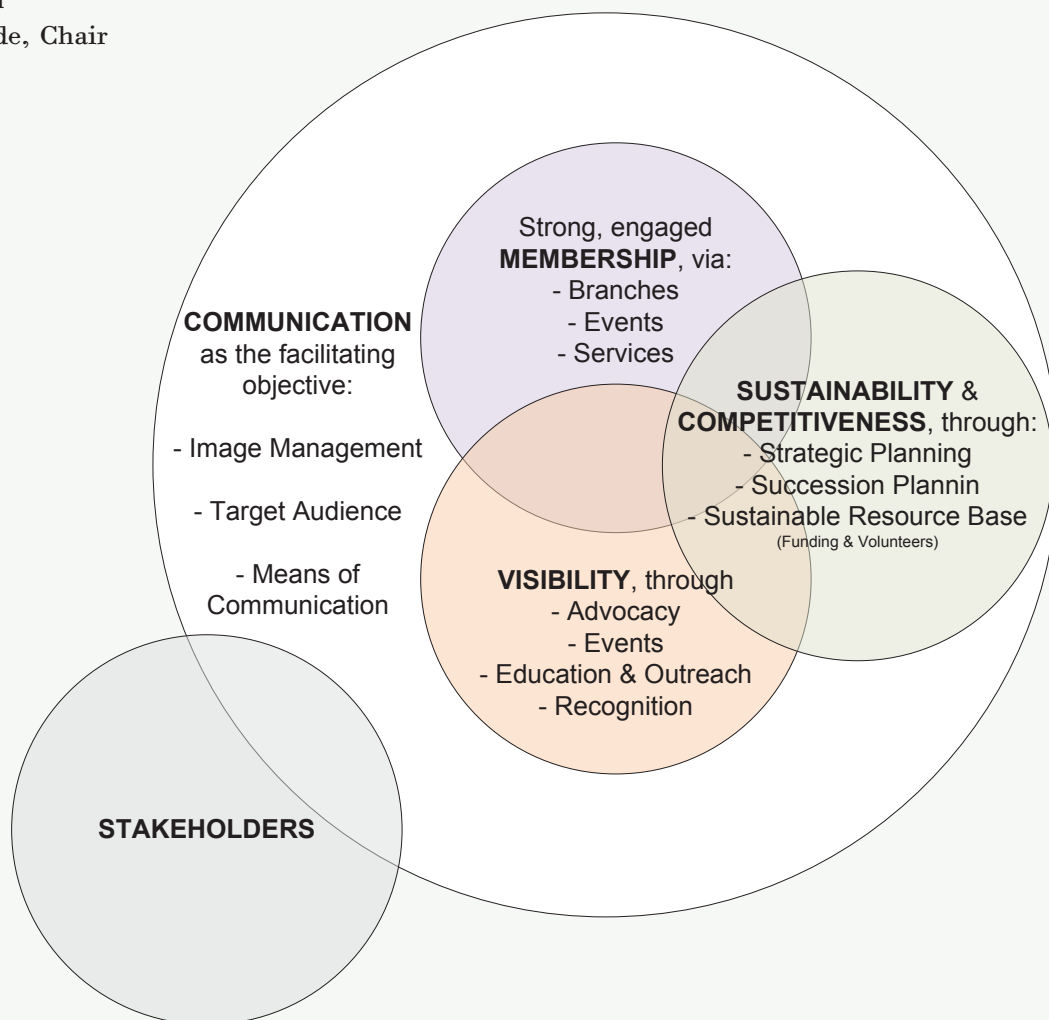
To detail these strategies and produce a living Strategic Plan now that input has been received from Extended Council, it is time to proceed with a simpler process and a smaller team:

The Strategic Planning Sub-Committee (reporting to the CNS Executive Committee)

Pauline Watson
Jerry Hopwood
Paul Thompson
Peter Easton
Chris Ciaravino
Michael Smith
Jacques Plourde, Chair

Terms of Reference are forthcoming and will include sub-committee objectives such as:

- Detailed strategies (what, by whom, by when, including metrics)
- Well defined ownership of the Strategic Plan and its preamble
- A periodic review and update process





Canadian Nuclear Society Société Nucléaire Canadienne

4th Floor, 700 University Ave, Toronto, ON M5G 1X6
Tel: (416) 977-7620 E-mail/Courriel: cns-snc@on.aibn.com

Scholarships in Nuclear Science and Engineering at Canadian Universities

The Canadian Nuclear Society (CNS) is pleased to offer scholarships to promote Nuclear Science and Engineering to students at Canadian universities.

Two scholarships are offered in 2017: One graduate school entrance scholarship of \$5,000 and two undergraduate summer research scholarships of \$3,000 each.

Graduate School Entrance Scholarship: \$5,000

This entrance scholarship is designed to encourage undergraduate students to enter a graduate program related to Nuclear Science and Engineering at a Canadian university.

Eligibility

You must be currently enrolled in a full-time undergraduate program at a Canadian University and be a member of the CNS.

The duration of the graduate program must be at least two years and is expected to lead to a Master's or a PhD degree.

Undergraduate Student Research Scholarship: \$3,000

This scholarship is designed to encourage undergraduate students to participate in research in Nuclear Science and Engineering during the summer months.

Eligibility

You must be enrolled in a full-time undergraduate program at a Canadian University for at least two years and be a member of the CNS.

The scholarship is to be matched by \$2,000 from the student's supervisor for a total of \$5,000.

The recipients of the scholarships will be selected on the basis of their academic standing and other information to be supplied with the application.

The Scholarship Committee of the Canadian Nuclear Society will collect and review the submissions, and make the award decisions.

Details of the scholarships and the procedure for application can be found on the CNS website at

www.cns-snc.ca/Scholarships

The deadline for submission of the application is **March 1, 2017**.



Canadian Nuclear Society Société Nucléaire Canadienne

4th Floor, 700 University Ave, Toronto, ON M5G 1X6
Tel: (416) 977-7620 E-mail/Courriel: cns-snc@on.aibn.com

Bourses en science et génie nucléaire dans les universités canadiennes

La Société Nucléaire Canadienne est heureuse d'offrir des bourses afin d'encourager les étudiants dans les universités canadiennes à étudier la science et le génie nucléaire.

Deux bourses sont offertes en 2017: une bourse de 5,000\$ à l'entrée aux études supérieures, et deux bourses de recherche d'été (de 3,000\$ chaque) pour étudiants poursuivant la licence.

Bourse d'entrée aux études supérieures : 5,000\$

Le but de cette bourse est d'encourager les étudiants à s'inscrire aux études supérieures en science et génie nucléaire dans une université canadienne.

Éligibilité

L'étudiant(e) doit être présentement inscrit(e) plein-temps à un programme poursuivant la licence dans une université canadienne, et doit être membre de la SNC.

L'échéancier du programme en études supérieures doit couvrir une période minimale de deux ans, et devrait mener à une maîtrise ou à un doctorat.

Les gagnant(e)s des bourses seront sélectionné(e)s à partir de la qualité de leur dossier académique, ainsi que d'autres données à être fournies en même temps que la demande de bourse.

Le Comité des bourses de la Société Nucléaire Canadienne recevra et étudiera les candidatures, et attribuera les bourses.

Les détails des bourses et les procédures de demande sont disponibles sur le site web de la SNC à

www.cns-snc.ca/bourses

La date limite pour la soumission de demande de bourse est le **1er mars 2017**.

Bourse de recherche pour étudiants poursuivant la licence : 3,000\$

Le but de cette bourse est d'encourager les étudiants poursuivant la licence à participer en recherche en science et génie nucléaire pendant l'été.

Éligibilité

L'étudiant(e) doit être inscrit(e) plein-temps à un programme d'au moins 2 ans poursuivant la licence dans une université canadienne, et doit être membre de la SNC.

Cette bourse doit être complétée par un montant de 2,000\$ de la part du directeur de la recherche, pour un total de 5,000\$.

2015-2016 CNS Council • Conseil de la SNC

Executive / Exécutif

President / Président	Peter Ozemoyah 289-288-0490 x249 pozemoyah@tyne-engineering.com
Past President / Président sortant	Paul Thompson 506-659-6234 pthompson@nbpower.com
1st Vice-President / 1er Vice-Président	Daniel Gammage 519-621-2130 x2166 dgammage44@gmail.com
2nd Vice-President / 2ième Vice-Président	John Luxat 905-525-9140 x24670 luxatj@mcmaster.ca
Treasurer / Trésorier	Mohamed Younis 416-592-6516 mohamed.younis@amecfw.com
Secretary / Secrétaire	Colin G. Hunt 613-742-8476 colin.hunt@rogers.com
Financial Administrator / Administrateur financier	Ken L. Smith 905-828-8216 unecan@rogers.com
Executive Director / Directeur exécutif	Ben Rouben 416-663-3252 roubenb@alum.mit.edu
Communications Director / Directeur des communications	Jeremy Whitlock 613-584-3311 x44265 jeremy.whitlock@cni.ca

Members-at-Large / Membres sans portefeuille

Parva Alavi	905-599-9534
Farzad Ardeshiri	905-858-3468
John Barrett, CNA	613-237-4262
Frederick C. Boyd	613-823-2272
Chris Ciaravino	416-697-4170
Rudy Cronk	905-949-2755 x 214
Ruxandra Dranga	613-584-3311 x 46856
Peter Easton	613-863-1027
Mohinder Grover	416-499-5591
Jerry Hopwood	905-823-9060 x 37507
Kris K. Mohan	905-332-8067
Dorin Nichita	905-721-8668
Nicholas Preston	289-200-9718
John G. Roberts	519-396-8843
Wei Shen	613-996-0192
Michael Smith	647-687-7112
Nick Sion	416-487-2740
Keith Stratton	506-343-4060
Ronald Thomas	613-236-3297
Kamal Verma	905-823-9040 x 35947
Pauline Watson	905-338-3032
Stephen Yu	905-823-9040 x 32179

CNS Committees / Comités de la SNC

Program / Programme	Keith Stratton 506-343-4060	kstratton@bellaliant.net
WiN Interface / Interface avec WiN	Pauline Watson 905-338-3032	watson@engspol.com
Branch Affairs / Chapitres locaux	Ron Thomas 613-236-3297	rthomas@storm.ca
Education and Communications / Éducation et communications	Ruxandra Dranga 613-584-3311 x46856	ruxandra.dranga@cni.ca
Membership / Adhésion	Ben Rouben 416-663-3252	roubenb@alum.mit.edu
Finance / Finances	Mohamed Younis 416-592-6516	mohamed.younis@amecfw.com
Bulletin	Colin Hunt 613-613-742-8476	colin.hunt@rogers.com
Past Presidents / Anciens présidents	Paul Thompson 506-659-6234	pthompson@nbpower.com
Honours and Awards / Prix et honneurs	Ruxandra Dranga 613-584-3311 x46856	ruxandra.dranga@cni.ca
International Liaison Committee / Liaisons internationales	Kris Mohan 905-332-8067	mohank@sympatico.ca
	Fred Boyd 613-592-2256	fboyd@sympatico.ca
Internet / Internet		
Inter-society Relations / Relations inter-sociétés	Peter Ozemoyah 289-288-0490 x249	pozemoyah@tyne-engineering.com
Young Generation / Jeune génération	John Roberts 519-396-8843	alchemy@tnt21.com
Scholarship / Bourses	Mohamed Younis 613-592-2256	mohamed.younis@amecfw.com
		416-592-6516

Technical Divisions / Divisions techniques

• Nuclear Science & Engineering / Science et génie nucléaires	Elisabeth Varin 514-953-9790	varine@gmail.com
• Fuel Technologies / Technologies du combustible	To 2014 October 7:	
	From 2014 October 8:	
	Paul Chan 613-541-6000 x6145	paul.chan@rmc.ca
• Design and Materials / Conception et matériaux	Daniel Gammage 519-621-2130 x2166	dgammage@babcock.com
• Environment & Waste Management / Environnement et gestion des déchets	Parva Alavi 905-599-9534	parvaalavi@gmail.com
• Nuclear Operations & Maintenance/ Exploitation nucléaire et entretien de centrale	Aman Usmani 416-217-2167	aman.usmani@amec.com
	Polad Zahedi 905-839-6746 x4029	polad.zahedi@opg.com
• Medical Applications and Radiation Protection/ Applications médicales et protection contre les rayonnements	Nick Sion 416-487-2740	sionn@sympatico.ca
• Fusion Science and Technology / Science et technologie de la fusion	Blair Bromley 613-584-3311 x43676	blair.bromley@cni.ca

CNA Liaison / Agent de liaison avec l'ANC

John Barrett	613-237-4262	barrettj@cna.ca
------------------------	--------------	-----------------

CNS Bulletin Publisher / Éditeur du Bulletin SNC

Colin Hunt	613-220-7607	colin.hunt@rogers.com
----------------------	--------------	-----------------------

CNS Bulletin Editor / Rédacteur du Bulletin SNC

Ric Fluke	416-592-4110	rfluke@sympatico.ca
---------------------	--------------	---------------------

CNS Office Manager / Bureau de la SNC

Bob O'Sullivan	416-977-7620	cns-snc@on.aibn.com
--------------------------	--------------	---------------------

Branches / Chapitres locaux

Bruce	John Krane	519-361-4286 jck@bmts.com	Ottawa	Ken Kirkhope	ken.kirkhope@cns-ccsn.gc.ca
Chalk River	Andrew Morreale	613-584-8811 x 42543 morreale@mcmaster.ca	Québec	Michel Saint-Denis	514-875-3452 michelstdenis@videotron.qc.ca
Golden Horseshoe	Jason Sharpe	905-975-5122 jason.r.sharpe@gmail.com	Sheridan Park	Raj Jain	raj.jain@candu.com
Manitoba	Jason Martino	204-753-2311 x62229 martinoj@cni.ca	Toronto	Andrew Ali	andrew.ali@amecfw.com
New Brunswick	Derek Mullin	506-650-3374 dmullin@nbpower.com	UOIT	Cristina Mazza	905-728-6285 mariachristina.mazza@gmail.com
			Western	Jason Donev	403-210-6343 jmdonev@ucalgary.ca

CNS WEB Page - Site internet de la SNC

For information on CNS activities and other links – Pour toutes informations sur les activités de la SNC

<http://www.cns-snc.ca>

2016

October 9-13

NUTHOS-11

Gyeongju, South Korea
cns-snc@on.aibn.com

2017

May

CANDU Maintenance and Nuclear Component Conference (CMNCC-2017)

Toronto, Ontario
cns-snc@on.aibn.com

June 4-7

**37th CNS Annual Conference
& 41st CNS/CNA Student Conference**
Niagara Falls, ON
cns-snc@on.aibn.com

July 31-Aug. 4

**13th International Topical Meeting on
Nuclear Applications of Accelerators
(AccAPP17)**
Quebec City, QC
cns-snc@on.aibn.com

Sept. 24-27

**2nd International Meeting on
Fire Safety and Emergency Preparedness
for the Nuclear Industry (FSEP 2017)**
Toronto, ON
cns-snc@on.aibn.com

Job Searching Made Easy!

In partnership with the Engineering Institute of Canada and 11 member societies, EngineeringCareers.ca is a **free** job site that helps Engineering professionals find great new career opportunities in various disciplines across Canada.

New positions are posted daily, so visit us today!
There are over 9,000 of your peers already looking.



**The
Engineering
Institute
of Canada**

EngineeringCareers.ca



Avoiding Faster Horses

by JEREMY WHITLOCK

It could very well be the case that mankind is not ready for nuclear energy.

Nor womankind either, for that matter (and in fact, public polling indicates even less so).

We've tried - oh, we've tried. It's been 65 years since electricity was first squeezed from the atom (EBR-1), and almost that long since the first large-scale civilian power plant (Shippingport). Where are we today?

As a species we largely remain locked out from accessing over 99% of nature's energy. We build reactors by exception, not the rule, and our designs haven't advanced much for half a century: If reactors were cars we'd all be driving Model-A's (good designs, but so much potential!).

We worship the least efficient energy resources on the planet like Neanderthals just happy to be getting by. Our altars to the Sun and Wind dot the landscape, doing their part to soothe our guilt for industrializing our planet so quickly over the last 200 years.

This past summer saw a number of civil society groups gather in Montreal for a conference dedicated to creating a "Nuclear-Fission-Free World". They produced a "Montreal Declaration" - now out for broader signature - recognizing "each nuclear reactor as a repository of the most pernicious industrial waste ever known."

Importantly, this isn't anti-nuclear weapons or anti-nuclear power - it's anti-nuclear fission. It is to technology as Donald Trump is to immigration: Just Stop It. No more fission until we know what the hell is going on. Build a wall and make the physicists pay for it.

(Yes I know what you're thinking: physicists aren't stopped by walls - they'd just tunnel through, with a probability of success they can annoyingly calculate.)

Of course nuclear fission isn't the first innovation to incite fear and loathing.

The automobile was one of the first game-changers to scare the bejeezus out of people - leading to laws that required someone to walk ahead of the murderous machines with a red flag.

Famous librettist W.F. Gilbert once dryly expressed his support for the shooting of motorists - noting that it "would appeal strongly to the sporting instincts of the true Briton, and would provide ample compensation to the proprietors of eligible road-side properties for the intolerable annoyance caused by the enemies of mankind."

A U.S. Congress report decried "the menace to our people of vehicles of this type, hurtling through our streets and along our roads and poisoning the atmosphere... In addition the development of this new power may displace the use of horses, which would wreck our agriculture."

A century earlier it was the locomotive earning the scorn of decent people everywhere, one observer protesting that "nothing is heard but the clanking iron, the blasphemous song, or the appalling curses of the directors of these infernal machines."

The professionals agreed: Dr. Dionysus Lardner, Professor of Natural Philosophy and Astronomy at University College, London, warned that "rail travel at high speed is not possible because passengers, unable to breathe, would die of asphyxia."

It is natural, of course, that innovation wouldn't be universally embraced - in fact, the more innovation, the less embracing.

Least of all, it would seem, is the embracing by those you'd think might stand the most to gain: Western Union famously snorted: "This 'telephone' has too many shortcomings to be seriously considered as a practical form of communication. The device is inherently of no value to us."

In 1977 (four years before the IBM PC) Ken Olson, founder of Digital Equipment Corporation, foretold that "there is no reason anyone would want a computer in their home."

In 1901 Wilbur Wright, two years before Kitty Hawk, declared that "Man will not fly for 50 years."

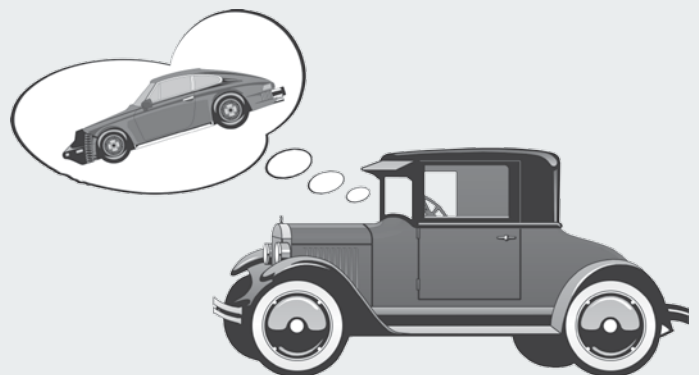
In 1926 Lee de Forest, American radio pioneer, predicted that television, "while theoretically and technically may be feasible, commercially and financially it is an impossibility - a development of which we need waste little time dreaming."

The fact is, light bulbs don't turn on in all heads at once. (To wit, the light bulb itself was said by a British Parliamentary Committee in 1878 to be "good enough for our American friends, but unworthy of the attention of practical or scientific men.")

Fortunately pessimism is often the catalyst for change, a credo that Hungarian genius Leo Szilard embodied in his nuclear chain reaction patent, filed shortly after hearing Ernest Rutherford famously scoff that "anyone who expects a source of power from the transformation of these atoms is talking moonshine."

But pessimism on a societal scale is a catalyst for catastrophe. The key to the above game changers is that they weren't put to a referendum (otherwise, as Henry Ford allegedly pointed out, "if I had asked people what they wanted, they would have said faster horses.")

We still sell nuclear fission like the people don't matter. Hoping, I suppose, that what happens in Montreal, stays in Montreal.



CANADIAN NUCLEAR LABORATORIES

CANADA'S PREMIER NUCLEAR SCIENCE ORGANIZATION



Canadian Nuclear Laboratories is a leader in nuclear science and technology offering unique capabilities and solutions through its expertise in metallurgy, analytical chemistry, biology, physics, and engineering. CNL provides comprehensive nuclear services and capabilities across the entire nuclear life cycle. Offering industry-driven solutions in Energy, Health, Environment, Safety and Security, we deliver innovative problem solving to keep industry competitive.

Depending on your requirements, we may work with or through trusted nuclear suppliers to deliver the best solution to you. In these cases, we will consult with and advise you on the most appropriate path forward.

For more information, please contact us at commercial@cnl.ca or visit us at cnl.ca/commercial.



Canadian Nuclear
Laboratories

Laboratoires Nucléaires
Canadiens

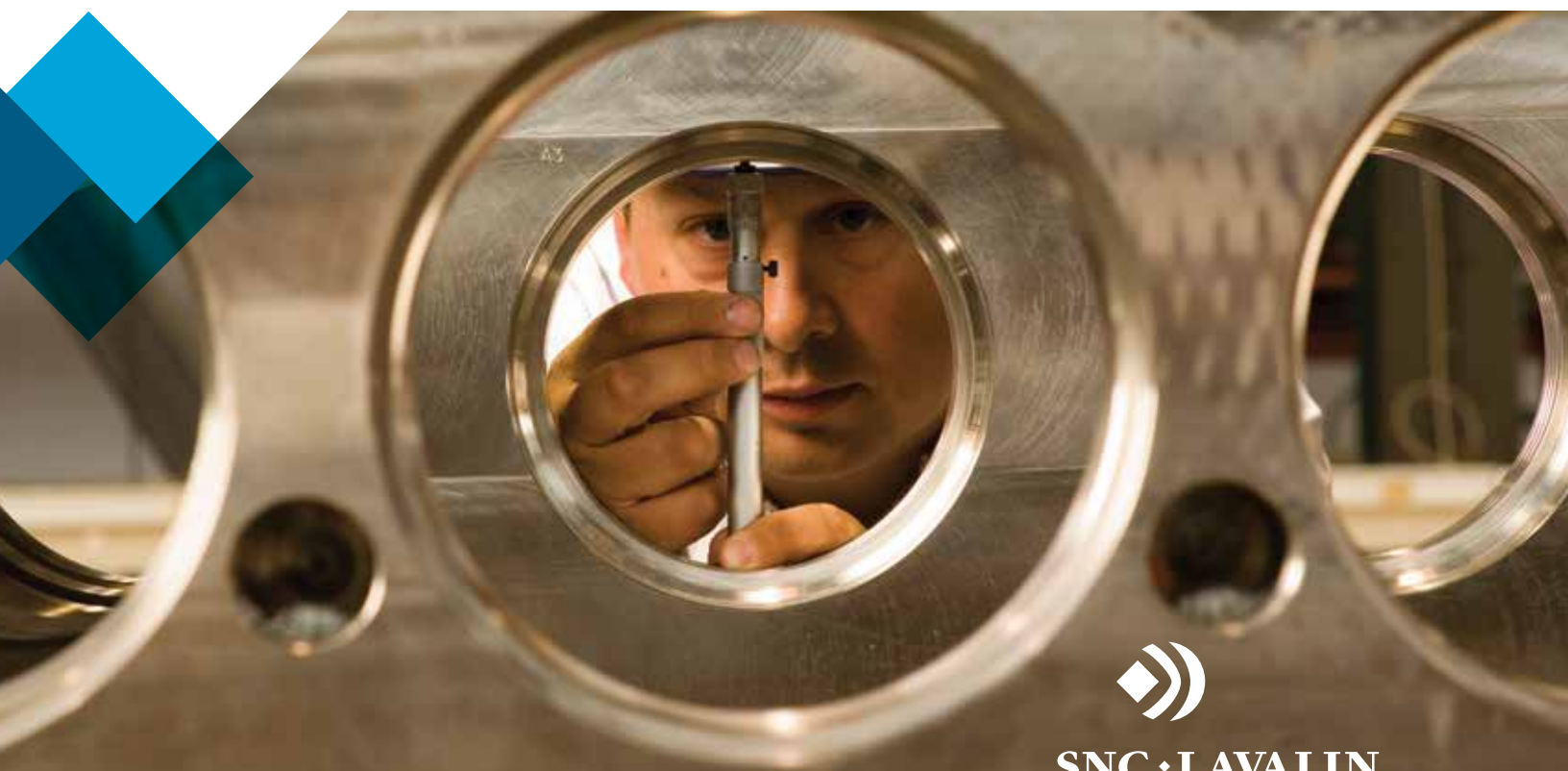
We'll service your nuclear reactor as if it were our own

Not only do we design and build reactors, we're also the best people to service and maintain them. For over 60 years now we have been developing and designing reactors to produce safe nuclear energy. As the original equipment manufacturer of the CANDU® reactor and close affiliation with Canadian Nuclear Laboratories, our full suite of engineering and field services meets the highest safety and regulatory standards.

With such a breadth of experience comes a level of expertise that proves invaluable in servicing both heavy and light water reactors. Working with our Nuclear team makes business sense. Speak to us about our reliable and innovative solutions:

BWR, PWR & CANDU PLANT MANAGEMENT | LIFE EXTENSION DECOMMISSIONING | OPERATIONS AND MAINTENANCE

   snclavalin.com/nuclear



SNC • LAVALIN

Building what matters