CANADIAN NUCLEAR SOCIETY

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DE LA SOCIÉTÉ NUCLÉAIRE CANADIENNE

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SILVER TSUNAMI – A Lost Generation

There is an interesting news article entitled "Special Report - Nuclear's lost generation" by Sylvia Westall [OLKILUOTO, Finland (Reuters), November 29, 2010]. She observes that the majority of people building Areva's EPR at Olkiluoto are in their late 50's or early 60's, with a few in their 30's, and hardly any in between. This is the new reality. To meet the growing demand for clean energy, companies, governments and regulators are scrambling to recruit and train nuclear engineers, scientists, trades and skilled workers. The need is urgent: EDF, for example, expects 50% of its current workforce to retire in the next five years.

Why? We need to look back a few decades.

In the early 1940s there was world interest in understanding the theories of nuclear physics, especially in Canada. With the building of the first Pile in September 1940 [see Bulletin Vol. 30, No. 3 (September 2009)], a controlled nuclear chain reaction became a reality. More scientists became educated which led to the 10-watt ZEEP reactor in 1945. In 1947, the 44 MW NRX reactor, the most powerful in the world, allowed even more scientists and students to carry out experiments. These research reactors crystallized a nation to realize the commercial and societal benefits of nuclear energy.

That growing pool of human talent built the 200-MW NRU reactor in 1957 which continues to operate. In 1960 the ZED-2 research reactor came on line and by 1962 Canada's first commercial nuclear electric generator, the Nuclear Power Demonstration (NPD) reactor, supplied electricity for the Ontario power grid.

The growth in skilled and knowledgeable human resources was primarily a result of having the best available research reactors in the world. This pool of human talent went on to build Douglas Point, before NPD was "proven", and before Douglas Point was commissioned they began building Pickering, and before Pickering was commissioned they began building Bruce. This could not have occurred in the absence of a large generation of people with the necessary training and experience, brought about by research reactors between 1940 and 1960.

Although new orders for nuclear halted abruptly in 1979 after the Three Mile Island accident, the CANDU was largely unaffected and the Darlington nuclear power plant was constructed in the 1980s. However, the Chernobyl catastrophe in 1986 sealed nuclear's fate for the next 20 years, long enough to lose an entire generation. University applicants in nuclear programs dwindled. The "Silver Tsunami" of nuclear workers began and they were not replaced.

As we celebrate the 50th anniversary of the ZED-2 reactor we need to also reflect on the vital role of a research reactor in developing human talent. Demand for nuclear power reactors around the world has suddenly increased but we have lost a generation of skilled people. Having world class nuclear research reactors, such as the McMaster Nuclear Reactor, NRU, ZED-2 and others, is what attracts students to enrol in nuclear programs, and carry out research projects using "hands on" facilities. The benefits are enormous – breakthroughs medicine, materials, archaeology and geology, to name a few.

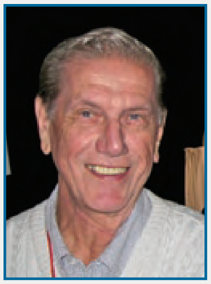
Building human talent cannot start with a crash hiring spree. It takes a long time to develop human talent and it takes having the right tools and facilities for higher learning. The NRU has had some bad days of late and may soon need to be retired. If Canada is to continue to develop human talent for the benefit of society, and if we are to be successful in building new Canadian power reactors, especially in Ontario, we need to strongly consider building a Multi-Purpose Research reactor in Canada.

In This Issue

This year marks the 50th anniversary of the ZED-2 research reactor and was the focus of the Technical Meeting on Low Power Critical Assemblies and Small Reactors (see conference report and related articles). A special memorial plaque was presented by the ANS president **Joe Colvin**, recognizing the ZED-2 as a Nuclear Historic Landmark. There were two other technical conferences that are summarized in this edition, on Nuclear Plant Chemistry and the International Conference on CANDU fuel. In both of these conferences the highly specialized and diverse pool of knowledge was evident.

In the September edition **Neale Hunt** of the Nuclear Waste Management Organization spoke of plans for the long-term management of used nuclear fuel. In response, **Peter Ottensmeyer** (UoT) presents an interesting alternative to disposal – extract its inherent energy to generate electricity. We also have a technical paper by **Dan Meneley** on the future challenges of nuclear energy. There are a number of news items and, of course, a double take by **Jeremy Whitlock** in his Endpoint.

Another year comes to an end and another one begins – a time to reflect on 2010 and anticipate success in 2011. I wish you and your families a safe and joyous holiday and prosperity for the New Year!



The Society

The Canadian Nuclear Society has been very busy this fall, having presented three conferences in a period of a month and a half. They were: *NPC 2010 (the 15th International Conference on Water Chemistry of Nuclear Reactor Systems); the 11th International Conference on CANDU Fuel; and the Technical Meeting on Low-Power Critical Facilities and Small Reactors.* The last one was really a celebration of the 50th anniversary of the ZED-2 facility at the Chalk River Laboratory.

These three gatherings, each focussed on a specific technical subject, provide a glimpse into the breadth and diversity of the technologies associated with nuclear reactors. It was fascinating to be part of these events, even when just the titles of some of the papers were unfathomable to one who has been more of a "generalist" than a specialist. There is no doubt that operation of a nuclear reactor, power or research, requires many specialists and it is reassuring to see that there are many individuals who are prepared to accept the challenge to become deeply knowledgeable about a complex subject.

There are reports on each of these in this issue but no report can capture the efforts of the many persons involved in the planning and executing of the events, almost all volunteers. While the events were sponsored by the Society many of those involved were not members. Which raises a question – why ? All were very interested in the subject matter of the conference in which they were involved but presumably not particularly concerned about the broader aspects of our nuclear program which the CNS tries to represent.

This, I suggest, presents a challenge to those of us who believe in the value of the Canadian Nuclear Society as an organization that can bring together people of different disciplines, with varying interests, to enhance the level of achievement of our Canadian nuclear program. We need to reach out, especially to those interested enough to work on a specific conference, to entice them in to be part of the broader scope of the Society.

The Society is keeping busy. As noted elsewhere in this issue, the Society is embarking on a new venture in taking on the publishing of the Nuclear Canada Yearbook and has published a "brief" on the need for a new research reactor. Although both are "publications" the nature of each is quite different, as is the Bulletin. Each has a distinct focus and intended readership.

Further, two new divisions have been added – *Medical Applications and Radiation Protection* and *Fusion Science and Technology*. For those who might raise the question, there is no intention that the former one should compete in any way with the Canadian Radiation Protection Association.

Our nuclear program

There have actually been some positive events in the past few months to partially offset the continuing gloom of uncertainty posed by our federal government's decision to, essentially, abandon the seven decades of achievement of our nuclear program.

Bruce Power has completed the insertion of the calandria tubes in both Unit 1 and 2 while Korea Hydro and Nuclear Power has actually replaced not only the calandria tubes but also the pressure tubes and end fittings on the Wolsong 1 unit. That latter achievement does suggest a lesson. Thirty years ago AECL built Wolsong 1 essentially as a "turn-key" project. Now Korea has a strong domestic nuclear power program based on their own designs and are exporting to the UAE. Having had considerable involvement with the Korean program this is not surprising. The program is focussed with strong support from the highest level of government and is coordinated. Equally, if not more important, is the Korean propensity for attention to detail and thoroughness.

It was no surprise to me that they observed the planning for the Point Lepreau refurbishment improved on it and executed it.

In the related area of uranium mining Cameco has finally found a way to develop their rich Cigar Lake deposit after the disastrous underground flooding of a couple of years ago. The company feels sufficiently confident that it has entered into a many-year contract with China to supply a significant part of that country's demand to fuel their growing number of nuclear power plants.

Here at home the Ontario government has announced its "new" electricity plan which is very similar to that of three years ago and, as in the earlier one, restates the province's intention to build new nuclear power units as well as refurbishing some of the existing ones. Of course, the caveat attached to their proposal to build new units is the move of the federal government to sell the engineering component of AECL.

In any event we have come to that artificial marking of time – the end of one year and the beginning of a new one. May all who read this have a pleasant holiday season and a fulfilling new year.

Fred Boyd

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~ Cover Photo ~

The ZED-2 Reactor – 50 Years Young.

Photo courtesy of AECL

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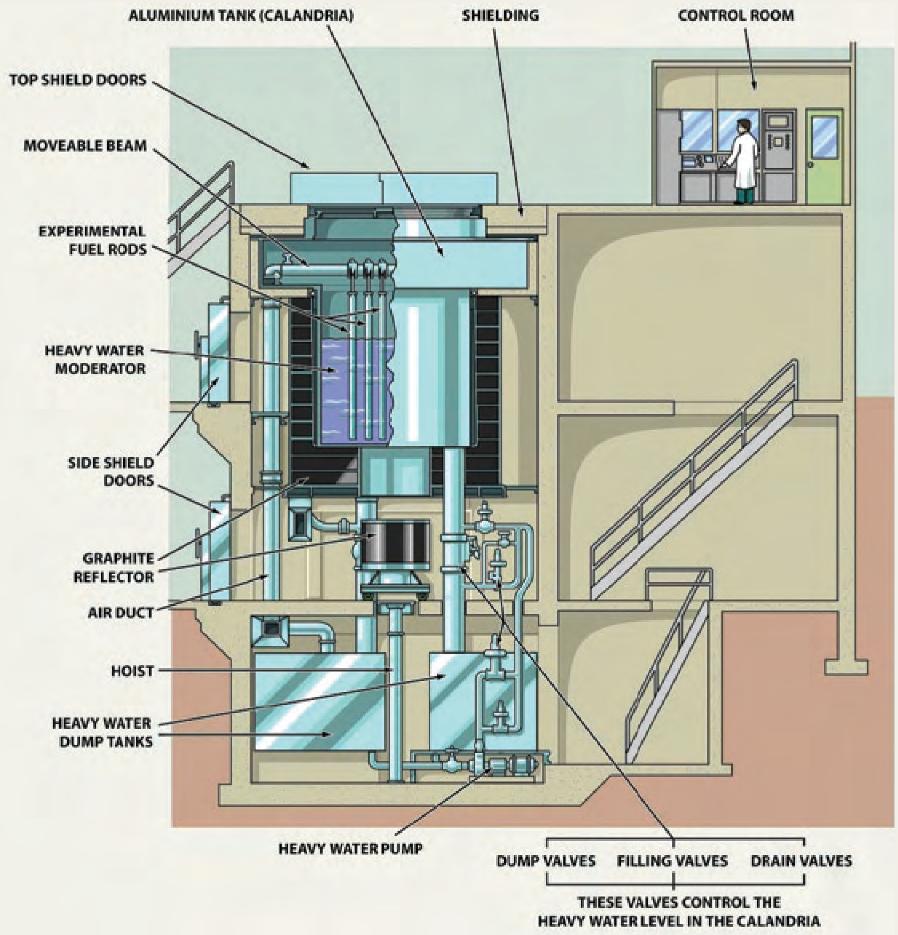
A History of ZED-2

by RICK JONES

General Background

The ZED-2 Reactor at Chalk River Laboratories was 50 years old this fall. First criticality occurred in September 1960. ZED-2 is perhaps not very well known in the Canadian Nuclear Industry, certainly not as well known as the various CANDU power reactors or the research reactors NRU and NRX. Part of the reason for this I suspect is that when casually judging the importance of reactors the first parameters that spring to mind are power generated (for power reactors) or neutron flux (for research reactors), bigger being "better" in both cases. By these standards ZED-2 does indeed appear puny: the maximum allowed power is 200W and the corresponding flux about 10^8 to 10^9 neutrons cm^{-2} s^{-1}, both numbers being about a factor of 500,000 smaller than the corresponding values for NRU.

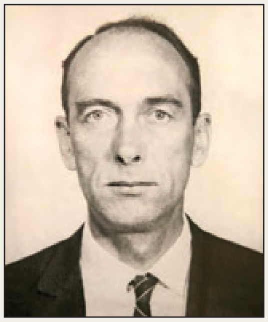
So, what is it all about? How is it that such an apparently insignificant reactor has operated for 50 years?, longer than any other Canadian reactor except NRU and the McMaster Reactor. What is it used for? What contributions has it made to the Canadian industry? Maybe one might also ask for how long is it going to continue? Well, that's what this talk is about, although I think I will leave the final question to wiser heads than mine.



A schematic of ZED-2.

ZED-2 is a descendant of famous progenitors: starting with Enrico Fermi's first critical pile of graphite and uranium (created at the University of Chicago in 1942) through Canada's ZEEP (first reactor to go critical outside the USA) that went critical in 1945. These early critical facilities were first about proof of principle that a self sustaining nuclear chain reaction could be established and controlled in a reasonable sized facility and second, in the longer term, developing understanding of the underlying reactor physics and the development of theories and methods to accurately predict the important properties of critical assemblies generally.

ZED-2 Senior Physicists 1960 to 2005



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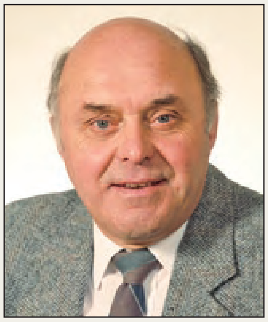

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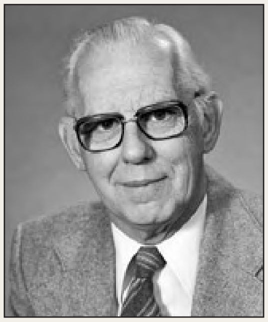


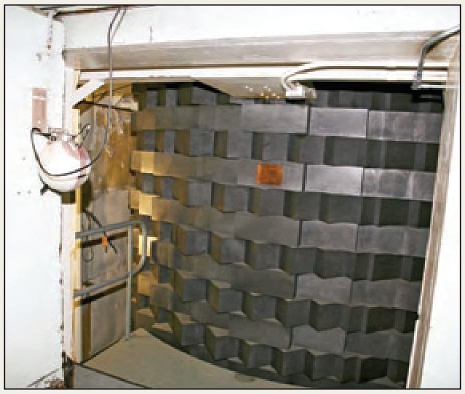
Dave Walker

Al Okazaki

Rick Jones

Control Room

Reactor Top



Graphite Reflector

One of the first measurements of interest is of the size that a given "lattice" of fuel and moderator must be to achieve criticality. This came to be embodied in a reactor physics parameter called the critical buckling, which I will not attempt to explain because the reactor physics community likes to maintain its little mysteries! Suffice it to say that it can be derived from the measured global flux distribution in a critical lattice.

In the early years of the Canadian program to develop what has become the CANDU power reactor system ZEEP proved large enough to investigate the lattices of 7-element and 19-element UO_2 fuel in a single 3" pressure tube, although including a calandria tube such as were used in the NPD and Douglas Point reactors proved impossible. This, combined with the realisation that to develop an economically viable and competitive power reactor system a larger diameter fuel bundle in a correspondingly larger channel would be required lead to the design and development of a larger ZEEP that came to be called ZED-2.

Description of ZED-2

This vertical section of ZED-2 shows the facilities main features, with homo-technicus in the control room to give an idea of the scale.

The cylindrical tank or calandria in which the lattice is assembled is 3.3 m in diameter and 3.3 m deep. It is surrounded by a graphite reflector to reduce neutron leakage.

The fuel assemblies (typically simulations of CANDU channels five bundles long) are hung from stainless steel beams to form the lattice of interest. The beams are movable by a hydraulic system to facilitate rapid changes to the lattice pitch, although only while shut down!

Heavy water is stored in three dump tanks in the basement from where it can be pumped at carefully controlled rates into the tank. The reactor is controlled by adding D_2O by pumping and removing by draining (leakage control)

Heating and cooling systems are available to vary the temperature of the heavy water before pumping it into the tank.

Emergency shut down is achieved by opening three large flap valves to rapidly dump the moderator back into the basement tanks. Trips (flux level and rate of change) are derived from neutron detectors located in the bottom graphite reflector.

Rolling shields on the top allow access through hatches in a rotating lid. The lid can be removed for major core modifications and is required to minimise heavy water vapour loss and downgrading by ingress of light water from the air.

Measurements made in ZED-2.

I intend to review some of the experiments performed in ZED-2 during its life to date. There is no attempt at an exhaustive list, just some of the things I remember or was particularly interested in. I hope these will give an idea of what has been done and how this is related to the development of reactor physics in Canada and of the CANDU power reactor. Two main types of measurement are made: firstly reactivity measurements in terms of change in critical size (critical heavy water depth or buckling) corresponding to some change in the core, and secondly detailed reaction rate distribution measurements (fission rates, capture rates) in a single cell (fuel bundle and associated moderator PT and CT). The results obtained were used in the early days to tune the variable parameters in the computer codes used to calculate lattice properties (POOF, POWDERPUFS). These early codes were essentially recipes, based on good understanding of the physics involved, that calculated the homogenized cross-sections and other parameters required for the full core modelling codes based on neutron diffusion theory.

The first Decade, the 1960s

I was not involved with ZED-2 during this period (joined in 1973) and so can only recount what I remember having been told and what I read in reports. Certainly the first measurements were made with a core of 28-element natural UO_2 bundles in 4" Al channels (by Ken Serdula). These included measurements of critical size (buckling) as a function of lattice pitch with three coolants in the channel: heavy water, air, and HB40 organic. The temperature of the lattice was at room temperature throughout.

Measurements were also made in these cores of the impact of various shut off rod designs that were being proposed for use in CANDU reactors (By Al Okazaki)

Also of significance were early developments of techniques for measuring properties of a fuel lattice when only a few rods of that fuel were available. This so called substitution method was applied to studies of four natural uranium fuel types in a 37 element geometry. These were UO_2, Uranium Carbide, Uranium

Silicide, and Uranium metal. An important reason for interest in such techniques was of course to minimise costs: only 35 bundles of each fuel type were needed compared to about 275 for a full core. These methods of measurement and analysis were pioneered by Al Okazaki and Don Craig.

The Early 1970s

A major measurement was made on fuel from the first charge of 37-element bundles built for the Bruce reactors. Buckling measurements were made in various shaped cores of the square lattice used in the power reactors, both cooled with D_2O and by air. The coolant void reactivity, an important parameter in LOCA analysis, was important. Problems with these measurements arose because of boron contamination of the Al tubes purchased to simulate the Zr PT and CT of the power reactor lattice (cost saving again!)

All measurements so far had been made at room temperature except for some variation of the temperature of the D2O moderator (and with fresh fuel). At this time a method to heat the water coolant in 7 specially built rods to up to 300C was developed so that the impact of temperature changes on reactivity could be measured, again making use of the few rod substitution technique.

The late 70s and early 80s

This was the time of advanced fuel cycles when it was believed that the future of CANDU lay in the burning of recycled Pu or potentially U^{233} in a self sustaining thorium cycle. This belief was based on twin estimates of the amount of uranium available to mine and of the rate at which installed nuclear capacity would be added to meet the world's requirements.

ZED-2 measurements were made on $(Pu,U)O_2$ fuel manufactured in Italy, $(Pu,Th)O_2$ fuel manufactured in an alpha-active glove box fuel manufacturing facility at CRL, and on $(U^{233},Th)O_2$ fuel made in the same facility. Again to keep costs reasonable only a few rods of each fuel type were produced.

Unfortunately these measurements were barely completed before it was realised that if indeed CANDU's future involved advanced fuel cycles it would be a significantly more distant future than had once been thought.

Late 80's and 90s

At this point the future of ZED-2 seemed to be in considerable doubt, but happily (for those of us who worked in ZED-2) The CANDU utilities, the regulator and the coolant void reactivity came to the rescue. Questions were being raised about the values of reactivity being generated by the codes used in LOCA analysis which still derived fundamentally from a recipe type code (POWDERPUFS) that had been tuned to ZED-2 measurements on fresh fuel and at room temperature.

In collaboration with reactor physicists from the utilities and Sheridan Park an extensive program to provide code validation data for calculation of coolant void reactivity (CVR) was planned and executed under the umbrella of the CANDU Owners Group (COG). This program included the manufacture of 35 bundles of 37-element fuel at CRL whose composition attempted to represent that of mid burnup CANDU fuel for CVR measurements by the substitution method. In addition a major effort went into validation of the substitution method for CVR measurement and the capabilities of the ZED-2 hot sites were extended so that CO_2 could be used as the heat transfer medium in the coolant space thus allowing CVR to be measured for a channel temperature range up to 300C. The results of this program were in part responsible for the acceptance by the industry that it was time to give up the use of recipe cell codes and adopt a more modern code (WIMS-AECL was chosen) based on full solution of the neutron transport equation.

The 00s

At this point we come to the end of my involvement with and knowledge of the program in ZED-2. When I retired in 2005 a set of measurements had been completed on so called Low Void Reactivity Fuel that used a 43-element fuel bundle (CANFLEX) with neutron absorbers in the central element and slight enrichment in the rest of the bundle. This fuel was destined for use in the Bruce Reactors, but I do not know if it was ever actually adopted.

Following that, emphasis was shifting to measurements to support the development of the ACR. An extensive program was being developed to provide validation data for the codes which I am sure will see ZED-2 working well beyond 50 years.

Some Comments on Operation

The operation of ZED-2 has been the responsibility of a research division within AECL rather than of the Operations Division, as was the case for the NRX and NRU reactors. For most of its life the Senior Reactor Physicist reporting to the Director of the appropriate Research Division was responsible for safe operation and the operating staff consisted of technicians from the same division. Good relations with the Operating Divisions ensured that assistance with such matters of calibration and maintenance of safety systems was readily available. Safe operation of facilities like ZED-2 that are of necessity flexible in terms of the cores that can be installed, have limited shielding designed to provide protection during normal operation at low licensed power, and allow for easy access of staff to the core region, certainly provides many challenges. Pre Chernobyl such reactors had been responsible for the most damage to staff from radiation of any reactor type. Happily the safety record in ZED-2 has been excellent, perhaps in part due to the fact that the staff were always aware that if anyone was going to be injured it was them, there being very little possibility of damage to people outside the facility. In recent years the management structure and the documentation governing operation have been expanded to align more closely with those of other larger reactor facilities. I expect that this will not make the facility less safe if only because it has the effect of slowing down the rate at which experiments can be performed!

CNS Celebrates 50th Anniversary of ZED-2

Technical Meeting on Low-Power Critical Facilities and Small Reactors

by FRED BOYD

Triggered by 50th birthday of the ZED 2 reactor the Canadian Nuclear Society, with the cooperation of the International Atomic Energy Agency, sponsored a special event, held November 1 – 3, 2010, in Ottawa, Ontario. The focus was on both low-power critical facilities, like ZED-2, and on other small reactors, especially SLOWPOKE 2.

ZED-2 is a zero energy facility at the Chalk River Laboratories of Atomic Energy of Canada Limited. It was built in 1960 to replace ZEEP, the zero energy facility which had been built in1945 at CRL to experimentally check the physics design of the large research reactor NRX. ZEEP was the first reactor outside the USA.

Given the nature of the meeting the attendance was not large, about 65, but quite diverse, including designers of ZED-2, young researchers, and international experts.

Although the actual meeting took place in the downtown Marriott Hotel, the opening reception on the Sunday evening was held at the Canadian Museum of Science and Technology, in the east part of Ottawa, which has a display of the ZEEP reactor.

Bhaskar Sur, of AECL – CRL, meeting chair, and **Frank Doyle,** CNS Vice-President, opened the meeting on the Monday morning and then introduced **Richard Didsbury,** Director, Nuclear Science Division, AECL – CRL, who gave the opening address, which he titled, *Low Power Critical Facilities – Their Role in the Nuclear Renaissance.*

He began by suggesting that a renaissance might not occur without such facilities. Then he looked back to 1960 and the events of the time. It was the golden age of nuclear energy, he asserted, with the first nuclear power plants just coming on line, and then noted that ZED-2 started on September 7, 1960.

Jumping to the current situation he noted various studies of the desire for electricity worldwide and predictions of the need for as many as 5,000 new nuclear power plants. To achieve that, he said, we need commodities (materials, components, etc.), fuel (uranium), and human capital. The first two we have but the last is, he suggested, doubtful. Research facilities, such as ZED-2, are needed, he contended, to develop the knowledgeable people needed.

Next in this opening plenary session was **Terry Jamieson,** Vice President, Technical Support, Canadian Nuclear Safety Commission, who spoke on *The Role of the Regulator.* (Jamieson had just arrived that morning from Japan !)

He began by noting that the CNSC is marking 65 years of nuclear regulation in Canada this year. Its predecessor, the Atomic Energy Control Board, was created in 1945, the same year ZEEP started. Regulators need the technical knowledge that is derived from facilities such as ZEEP and ZED-2, he stated.

Then he turned to the CNSC licensing system and mentioned a new draft regulatory document, RD 367, *Design of Small Reactors,* which provides the design requirements for new small reactors. The document identifies the overall safety objectives to be achieved, key safety concepts - such as the principle of defence-in-depth, and the consideration of multiple physical barriers - and other important engineering principles. The first round of comments ended November 3, 2010 but further comments will be considered. It is expected that the document will be formally approved by the Commission in the spring of 2011.

In closing he noted that the Expert Panel on Radioisotopes had recommended a new multi-purpose reactor to replace NRU, whose operating licence will be up for renewal in early 2011. AECL has indicated it will be seeking a renewal to 2016 and discussions have been held about a further term.

That led into the topic of the next speaker, **Dominic Ryan,** of McMaster University and president of the Canadian Institute for Neutron Scattering, who titled his presentation, *Canada's New Multi-Purpose Reactor – Building A Future for R&D in Canada.*

He began by noting that he and his colleagues in CINS just use the neutrons from NRU but the research and the applications of neutron scattering are very important. As noted, NRU might continue operating until 2021, he said, but bluntly stated, "it is getting old" and must be replaced. However, a decision tree he presented implied a small reactor would suffice. There does not appear to be much support for a nuclear power program, he commented. His address elicited an active discussion.

Following a break, **Ray Sollychin,** of the International Atomic Energy Agency spoke on *A Look at the Role of Low Power critical Facilities and Small Reactors and the Needs of Member States Considering Nuclear Energy.* He said he wished to cover three topics: IAEA activities related to research reactors; the move to end the use of highly enriched uranium (HEU); and the role of small reactors as a first step towards a nuclear power program.

There have been 671 small research reactors built around the world, he said, of which 171 have been decommissioned and 247 shutdown. The reasons for these actions have included: lack of funding; ageing of both facility and staff; under-used; accumulation of spent fuel.

The move to remove HEU is motivated by proliferation concerns. He noted that the McMaster reactor had been converted to low enriched fuel.

Small reactors can provide some experience useful for a nuclear power program and the IAEA provides help and guidance, he commented, but have been largely underused for that purpose.

The final plenary presentation was on the initial motivation for the meeting, the history of ZED-2, and was given by **Richard Jones,** a retired physicist associated with the reactor.

He began by noting the reactor was primarily needed to test the nuclear behaviour of proposed power reactor fuel. The reactivity was controlled by the height of the D_2O moderator. A number of different reactor physics codes were used to evaluate the observations, such as POOF, POWDERPUFF, LATREP. In the 1970s the testing was mostly on heated fuel, in the 1980s it was advanced fuel designs and in the 1990s a major focus was on the problem of coolant void reactivity.

(His presentation notes are reprinted in this issue of the CNS Bulletin.)

The Monday afternoon and all day Tuesday were divided into three sessions of more detailed or focussed nature. The session titles were:

- Design, Safety and Licensing
- Analysis and Experimental
- Applications

Some of the presentations, however, were more general than the session titles implied.

Lloyd Cosby, of Nova Nuclear Support, in his paper titled, *Keeping Research Reactors Relevant – A Pro-Active Approach for SLOWPOKE-2,* spoke on the continuing upgrades to the SLOWPOKE at Royal Military College. These have included changing the control system from analogue to digital, adding a simulator, larger display and installing a new control rod drive.

Gerry Frappier, of the CNSC, spoke on *The Need of Test and Research reactors in Supporting Regulatory Technical Assessments.* He mentioned three examples of research and testing at NRU and ZED-2 supported the reviews and assessments by CNSC staff:

- The positive void reactivity coefficient issue
- Evaluation of new fuel designs such as LVRF
- Information to support the review of new reactor designs, such as the ACR 1000

There is a continuing problem of "unknown unknowns", he commented.

In the Tuesday afternoon session, **Chris Heysel,** Director, McMaster Nuclear Reactor spoke about the broad program for MNR under the title: *Overview of MNR: Where We ARE and where We are Going.* Back in 1995, the then president of McMaster proposed shutting down the reactor. A group of concerned people was convened and decided on a business approach, to have the reactor pay for itself. By selecting some medical isotopes that they were able to produce efficiently, adding a high flux beam for research and a number of other developments they were able to develop a business model for the reactor that is continuing.

He was followed by **Ron Rogge,** of the Canadian Neutron Beam Centre of the National Research Council. That is the group that uses the neutron beam from the NRU reactor for basic research. He outlined some of the applications, such as using neutron scattering to determine material structure at atomic level; and studying microscopic response of materials to external fields. This could be done with a smaller reactor that had sufficient flux density.

Lunch was provided each day and there was a dinner on the Monday evening at which Dan Meneley, former Chief Engineer at AECL, was the guest speaker.

During the lunch break on the second day a special presentation was made. Joe Colvin, president of the American Nuclear Society was able to be in Ottawa and presented a plaque designating ZED-2 as a Nuclear Historic Landmark. Michael Zeller accepted the plaque on behalf of AECL. *(See separate report in this issue of the CNS Bulletin.)*

The meeting was supported by: the IAEA; CANDU Owners Group; Canadian Nuclear Safety Commission; McMaster Nuclear Reactor.

CRL staff make adjustments for an experiment in the ZED-2.

photo courtesy of AECL

Nuclear Plant Chemistry 2010

CNS Hosts International Conference on Nuclear Plant Chemistry

by FRED BOYD

The week of October 3 – 7, 2010, the Canadian Nuclear Society hosted the **15th Nuclear Plant Chemistry Conference** in Quebec City, the first time it has been held in Canada. This was truly an international event with more than two thirds of the over 300 attendees being from outside Canada, mostly from Europe and the Far East.

With the formal title of: *International Conference on Water Chemistry of Nuclear Reactor Systems*, this was a very focussed conference. Other than the introductory talk by **Paul Spekkens**, V.P., Science and Technology, Ontario Power Generation, and Honorary Chair of the Conference, all of the presented papers and posters dealt with specific chemistry problems and solutions. *(Spekkens' comments are reprinted in this issue.)*

The conference was the 15th of a series that began in 1977 in Bournemouth, UK, and sometimes referred to as the "Bournemouth meetings". After the first few held in the same locale they have been located in various centres around the world. Unlike most conference series these are not authorized by a society. Rather, major societies are invited to sponsor and organize a conference by the "Core Members" of an International Corresponding Members Group consisting primarily of the organizers of past conferences. Potential host countries are approached two cycles (four years) in advance and invited to offer to host the conference.

Derek Lister

In keeping with this tradition **Derek Lister**, Research Chair, Nuclear Engineering at University of New Brunswick, held discussions with the International Corresponding Members Group (of which he is a Core Member) at NPC 2006 in Korea regarding Canada hosting NPC 2010. On his return a formal proposal was made to the governing Council of the CNS which agreed and appointed former CNS president **Bill Schneider** as Executive Chair to oversee the organization.

Bill Schneider

Derek Lister agreed to be General Chair. The challenging task of Technical Program Chair was assumed by **Peter Angell** of Atomic Energy of Canada Limited.

The four day program was arranged as a series of single sessions. There were 54 papers presented orally and close to a 100 as posters. The posters were classified in the same categories as the presented papers and set up in the refreshment lobby to provide visibility. There was a poster competition, with the judging by a large team led by **William Cook** of the University of New Brunswick who oversaw the organization of the poster program.

The oral presentations were strictly controlled on time and on the number of "slides" used. This resulted in the conference running closely on schedule which, in turn, allowed ample time for informal discussions.

The titles of the session give some indication of the subject matter of the papers and posters.

- PWR, VVER and CANDU/PHWR Operational Experience
- BWR Operational Experience
- BWR Scientific Studies
- Aging and Lifetime Management
- PWR, VVER, and CANDU/PHWR Scientific Studies
- Steam Cycle Operational Experience
- Water Treatment and Auxiliary Systems
- Chemistry and Fuel Performance
- Chemistry and NPP Performance
- Cleaning and Decontamination
- Future Developments

The session on PWR, VVER, and CANDU/PHWR Scientific Studies had the most number of papers and posters, followed by the one on Chemistry and NPP Performance.

Following the four day conference about 80 delegates convened for a one-day **Workshop on Radiolysis, Electrochemistry and Materials Performance**, organized and chaired by **John Roberts**, CNS 2nd Vice President. Its primary focus was the effect of radiation on corrosion. (John also became an active member of the organizing group of NPC 2010.)

When asked about the importance of chemistry in operating nuclear power plants, the primary organizers summarized it in the following statement:

> *Once a nuclear plant is in operation, chemistry improvement is the only way to increase the longevity of the plant and its equipment.*

On the Tuesday afternoon, delegates took a respite from the technical sessions to enjoy a bus tour of the Quebec countryside especially to show the many attendees from overseas the colours of the autumn forest. The tour circled the rustic nearby Ile d'Orléans and stopped at the renown Montmorency Falls.

A conference banquet was held on the Wednesday evening at the Quebec Museum of Civilization where delegates had a chance to view exhibits reflecting the history of the province.

Although most of the papers and posters dealt with very specific issues one from the International Atomic Energy Agency described an initiative aimed at providing a comprehensive approach. It had a very long title, *Optimisation of Water Chemistry to Ensure Reliable Water Reactor Performance at High Burnup and in Ageing Plant (FUWAC); An IAEA Coordinated Research Project.*

The project is attempting to compile information on the best practices around the world. This has included many studies such as clad oxidation from Russia and crud behaviour from several countries. Derek Lister, who is a member of the overseeing committee for this project, commented that the project goes well beyond fuel performance. The full report is scheduled to be issued in the IAEA "TechDoc" series by the end of 2010.

There was a specific effort to have a number of young people attend and participate in the conference. They added a vitality and distinct perspective. At the end of the conference four of them penned a note of appreciation. Following is an excerpt from that note.

We are writing in regards to the NPC 2010 conference. As students, we are accustomed to attending conferences with an academic focus. This year's NPC conference was a very different experience; the industrial perspective allowed us to see and understand how we, as students and researchers, fit into the nuclear industry. It was very interesting to expand our knowledge on the many different systems involved in the nuclear industry. Our conversations with global experts in the field were beneficial to our learning, and the experiences with such people will be remembered.

We especially enjoyed the workshop and the mixing of different "generations" of researchers and scientists at lunch. We heard stories ranging from practical experience in the work force, working with nuclear power and life lessons from around the world. The idea of mingling was very beneficial to us as students, and we hope that the veterans in the field enjoyed our company as much as we enjoyed theirs.

John Roberts

Daniel Gammage, of Babcock & Wilcox Canada oversaw the preparation of an advance CD before the conference. The Proceedings CD, which will include the PowerPoint presentations and a record of discussions, was scheduled to be released by the end of November. Copies may be obtained through the CNS office.

Financial assistance for the conference and workshop was organized by **Wendy Walker** of Pall Corporation. The sponsors and exhibitors were: AECL; Bruce Power; CCI Thermal Technologies; Dow Water &Process Solutions; Kinectrics; Lanxess Sybron; Ontario Power Generation; Pall Corporation; PUROLITE; Sanosil; Swan Analytical Instruments.

Eighth International Radiolysis, Electrochemistry and Materials Performance Workshop

This Workshop was held on the Friday following the NPC 2010 Conference.

Following is a note on the Workshop prepared by its chairman John Roberts.

The first Workshop was initiated by Professor Kenkichi Ishigure in 1998. The purpose of the Workshop was to attempt to gain some understanding of the irradiation assisted stress corrosion cracking which was occurring in the stainless steel of boiling water reactors. To Professor Ishigure's surprise the workshops have continued, as has the cracking which has since been observed in stainless steel of pressurized water reactors. The attendance at these Workshops has not exceeded 50 participants.

Historically this Workshop was held as an independent event following a Bournemouth series conference. The organisers of the 2010 Workshop and the NPC2010 conference decided that these two events would be held consecutively, as previous, but for the first time the organization and registration would be shared. This proved to be a winning combination.

We had hoped that fifty participants might attend our Workshop. To our great joy and surprise we had over one hundred participants, the majority of whom were from overseas. All presentations were of excellent quality.

The "state of the art" for BWRs and PWRs was discussed by Professor Ishigure formerly of Toshiba Corp. and now Executive Director of the Japanese Radioisotope Association. Dr. John Elliot, recently retired from AECL-CRL, who had produced the "G" values which are used, worldwide, to determine the corrosivity of the water around BWR and PWR coolant circuits, discussed "state of the art" for CANDU. The last of the many interesting presentations which specifically looked forward was by Dr. Dave Bartels of University of Notre Dame, Radiation Laboratory. The issue was whether or not hydrogen water chemistry will work in a supercritical reactor.

Participation by students was excellent and included two doctoral candidates from UWO who made presentations to the Workshop.

As a result of previous feedback from students a novel approach to the luncheon organization was tried. The Workshop Chair set the expectation that those having less experience (<10 years) would sit with those having more experience (>10 years) in radiolysis research and/or the nuclear industry. The feedback from the students and young attendees was very positive, recommending that such initiatives be continued. These interactions will help maximize the probability of those young persons joining/remaining the nuclear industry.

As with NPC2010 the Workshop started and finished within the advertised schedule.

Dr. Jean-Luc Bretelle, of EDF, who is charged with organizing the 2012 Bournemouth Conference and Radiolysis Workshop, stated that *"The CNS has set the standard by which future Bournemouth Conferences and Radiolysis Workshops will be measured"*.

In summary, the Eighth International Radiolysis, Electrochemistry and Materials Performance Workshop was a resounding success.

Opening remarks by Paul Spekkens, NPC 2010 Honorary Chair

Good morning ladies and gentlemen. It is a pleasure for me to add my welcome to you all to this important conference on Nuclear Plant Chemistry. It is impressive to see such a large group of chemists gathered in such a delightful location as Quebec City. And while the location of the meeting is certainly a factor, I'll bet that the main reason you've all chosen to come to this conference and the fact that your employers have sponsored you to attend this conference has more to do with value than with location. I think your attendance is a sign of the value that you and your employers place on the knowledge and insights that you will gain while you are here.

However, I suggest to you that you and your employers will only derive true value if the knowledge and insights you gain here cause you to do something different when you get back to your home organization.

If you are a researcher, it may cause you to pursue a different line of investigation or to approach a problem differently. If you are a consultant or a contractor, it may cause you to change the advice you provide or the products or services you offer. Most importantly, if you are directly affiliated with a nuclear power plant… and I say "most importantly" because the only reason to have a Nuclear Plant Chemistry conference is the worldwide fleet of several hundred reactors that rely on chemistry to protect and improve their safe, reliable and cost-effective operation.

If it weren't for the plants, there would be no point in having this conference…. so, most importantly, if you are associated with a nuclear plant or fleet of nuclear plants, it may cause you to look at your chemistry data differently, to consider revising something in your chemistry response practices or even to change some aspect of your chemistry regime. Making a change is important – if we don't change anything, it is either a sign that we feel that our chemistry program is already perfect (which I doubt very much any of us would say) or that we will have failed to take the learnings from the conference and turn them into some tangible improvement that delivers value for our plants. Coming to a conference like this and not making a subsequent change is a missed opportunity.

Where do you think you will learn the most at this conference? No doubt, some will come from listening to the formal presentations and reading the posters. But I believe that even more will come from the informal discussions and interactions you will have with each other during the conference. The active exchange of opinions and ideas is far more likely to spark a new thought than just listening or reading. So I hope you get to engage in those sorts of informal discussions over the next few days, and indeed seek them out.

Finally let me close by recognizing that a conference like this takes a lot of people and resources to pull together. I think the organizing committee has done a terrific job of pulling together an exciting technical program and wrapping a set of very strong conference facilities and activities around it. So if you get a chance to thank the people who have pulled this together please do so.

There's another group I'd like to recognize as they play an important role and that is the Core Members of the International Corresponding Members group. Their names are listed in the program along with the important role they play in evaluating the current conference, feeding that to the organizers of the next one and selecting the location of the one after that.

Also, we need to recognize that sponsorships are important to defray some of the costs of the conference, so that it keeps the individual cost of participating down. The sponsors are listed in the program, and there will be a number of reminders throughout the conference of who the conference sponsors. So please take a moment to recognize these organizations.

With that, let me welcome you again to NPC 2010 and to Quebec City, particularly those of you who have traveled a long way to be here. I think we'll have a terrific conference, so let me turn you over to Bill Schneider, our executive chair, for his opening remarks and then we can get the technical program started.

A reflection on the conference

The Challenge of Communication

by BILL SCHNEIDER, Executive Chair

To understand the significance of such a conference, one must first realize that once in operation, a nuclear plant can only degrade – and the only means of managing such degradation at that stage is by the improvement of operating chemistry.

Corrosion - the principle mode of process equipment degradation - is driven by: (i) material susceptibility, (ii) stress-state, and (iii) operating environment (chemistry). Once equipment is in operation it is too late to address Items (i) and (ii).

Conferences like this focus on the science and practice of operating chemistry needed to ensure that well-run [nuclear] plants will achieve their very long life-expectancies.

Plant chemistry scientists and practitioners are very focused on day-to-day operations. They communicate very well with each other via numerous forums, at the plant and at regional and international levels. However, communication with plant management, operations, owner, and service-provider communities is not always successful.

The problem is exacerbated by the focused-nature of communication within the chemistry community and the pre-occupation with arcane intricacies of the chemistry of the many systems. However, I believe that much of the problem lies with a wide-spread indifference by the broader operations community to the implications of operating chemistry on the long-term reliability of their plants.

Too often, plants proceed with hugely-expensive system and equipment repair or replacement projects without adequately addressing either the root-cause of the degradation, or measures for its prevention.

My message to the Operation and Maintenance Community is: *"An intense focus by the entire operations and support community on operating chemistry and on its management is vital to the reliability and longevity of nuclear plants – chemistry is the only life-management measure available once a plant has started up"*

My message to the Chemistry Community is: *"If you want to be heard by those in operations, speak first of boiler chemistry, of its corrosion product transport/ deposition implications; of its effect on flow accelerated corrosion, and of the aggressive species it may bring. Then go on to deal with the chemistry of the primary heat transport and ancillary systems. In that order you have a chance of engaging peoples' attention – go in the reverse and you may be met with more of those, all too familiar, glazed-over reactions"*

(Schneider's comments were edited for space limitations)

Conference Hotel

View of the poster area.

11th International Conference on CANDU Fuel

Versatility of CANDU highlighted

by FRED BOYD

The ability of the CANDU design to use many variations of fuel was highlighted at the *11th International Conference on CANDU Fuel* held in Niagara Falls 17 – 20 October 2010.

About 130 specialists in the design, manufacture, testing and operational use of fuel for CANDU reactors gathered to share their knowledge and experience. Among those attending were delegates from Argentina, Korea and Romania bringing their experience with the CANDU units in their countries and from India reporting on that country's numerous PHWR units based on an early CANDU design.

The conference was held in the Sheraton Fallsview Hotel which, as the name implies, does overlook both the Canadian Horseshoe Falls and the adjacent American ones. It began with a pleasant reception on the Sunday evening.

The conference proper began on the Monday morning with welcoming comments from Conference Chair, **Steve Palleck**, and Honorary Chair, **Joseph Lau,** followed by a plenary session on *International Experience*.

Steve Palleck

First on the program was **Dr. Raigin Narayana Jayaraj**, head of the Nuclear Fuel Complex in India, who began with an overview of the large Indian program. He titled his talk as *Consolidating Indigenous Capability for PHWR Fuel Manufacturing in India.* India now has 4,240 MWe of PHWR generation in operation with most of the units being of a design evolved from the Douglas Point with 220 MWe capacity, together with two units of 540 MWe capacity.

The Nuclear Fuel Complex began with one manufacturing plant in the 1970s. Now it has several facilities in various parts of the country. To date his organization has produced over 450,000 fuel bundles, some of which have been of a MoX design (including plutonium) and others enriched to between 0.9 and 1.1 % U235.

India has total self-reliance in PHWR technology, he stated in closing.

He was followed by **G. Horhoianu** from the Institute for Nuclear Research in Romania, speaking on *Load Following Tests on CANDU Fuel Elements in the TRIGA Research Reactor on INR Pitesti.* Two power cycling tests were conducted. One subjected the test fuel to 367 power cycles, the other to 251 cycles. "There was no evidence of fuel failure", he stated. Subsequently, one of the CANDU units at the Cernavoda site was operated successfully in several tests of a load-following mode.

An interesting and potentially positive development in the recycling of PWR fuel in a CANDU unit was part of a paper entitled *CANDU-6 Fuel Bundle Fabrication and Advanced Fuel Development in China* given by **Doug Burton** of Cameco on behalf of **Wang Jun** of the China North Nuclear Fuel Corporation.

The China North Nuclear Fuel Corporation (CNNFC) manufactures all of the fuel for the two CANDU 6 units at the Third Qinshan Nuclear Power Company (TQNPC). In recent years, CNNFC has introduced several modifications to the manufacturing process. Since 2005 there have been no in-core fuel failures in the two Qinshan CANDU units.

Most of the presentation was about recent tests of "Natural Uranium Equivalent" fuel developed by CNNFC. That is the term used to describe fuel composed of uranium extracted from spent PWR fuel and then blended with depleted uranium to make it similar to natural uranium.

Recent developments of spent fuel processing have resulted in the uranium being separated from the fission products and actinides. The radioactivity of the separated uranium is similar to that of natural uranium allowing the product to be handled without shielding or special conditions.

Since the separated uranium from the spent PWR fuel is typically of 0.9% U235 it was blended with depleted uranium to bring the U235 content down to the 0.7% of natural uranium. Since the resulting fuel bundles are almost identical to those prepared with natural uranium the need for special operating or licensing conditions is obviated.

As well as the NUE program, China is also pursuing the development of fuel employing thorium and is in the process of setting up a ThO_2 powder manufacturing facility.

(The announcement of the first NUE test irradiation was reported in the General News section of Vol. 31, No. 1 issue of the CNS Bulletin.*)*

After the break, **Jong Youl Park**, of the Korea Atomic Energy Research Institute, spoke on *Development and Commercial Implementation of CANFLEX Fuel in Korea.* Korea has 20 nuclear units operating and six under construction. Four are CANDU units at the Wolsong site, the remainder PWR.

He noted that KAERI, together with AECL, has been working on CANFLEX fuel since 1991. The design was developed to overcome a derating due to creep of the pressure tubes. It was first tested in Wolsong 1 in 2002. The tests were successful and it is proposed to load Wolsong units 2, 3, and 4, with CANFLEX fuel beginning in 2012.

The final presentation of this first plenary session was by **Ho-Chun Suk** of the Canadian Nuclear Safety Commission whose presentation was titled *CNSC Approach to the Review of Nuclear Fuel Systems Design for New Nuclear Power Plants.* He said the CNSC has developed a number of regulatory documents pertaining to fuel system design. These include; Regulatory Document RD 337 on the overall design of new nuclear power plants; Guide Document GD 369 on licence applications and Staff Review Procedure SRP 6.4.1. The SRPs outline the technical criteria to be used by staff in reviewing licensing submissions.

A second short plenary session was held on the Tuesday morning with three presentations.

The first was given by **John Roberts,** Cantech Associates, on behalf of his co-authors, G. Ma, M. McQueen, and R. Nashiem, of Bruce Power. The title was *Short, Medium and Long Term Consequences of Inadequate Defect Fuel Management.*

Roberts referred to the recently observed alpha contamination at Bruce as an example of inadequate defect fuel management. Among short term consequences he noted environmental issues from the release of Xe 133. Contamination of the fuel and coolant has led to increased radiation doses to fuelling machine mechanics. In the longer term contamination of the coolant can decrease the sensitivity of the delayed neutron detectors.

Digging back into history he mentioned a crushed fuel bundle in one of the Bruce A units in 1979. That caused the maintainers to don double plastic suits. The practice at Bruce B, he said, is to remove defective fuel as soon as possible after being detected.

Spent fuel transportation was the focus of the presentation by **G. Vieru**, of the Institute for Nuclear Research in Romania, titled, *Some Aspects on Security and Safety in a Potential transport of a CANDU Spent Fuel Bundle in Romania.*

The paper described a study on various potential routes for shipping spent fuel from the site at Cernavoda by road to his Institute for examination. Various accident scenarios were postulated and as a result a route has been chosen to minimize the risk to the public and environment.

In the last paper of that plenary session, **Brent Lewis** of the Royal Military College, described the extensive program developed after an Industrial Research Chair in Nuclear Fuel was established at RMC in 2007 for five years in partnerships with CANDU Owners Group (COG), University Network of Excellence in Nuclear Engineering (UNENE), Natural Sciences and Engineering Research Council (NSERC) and the Department of National Defence. The paper, titled *Overview of the UNENE/COG/NSERC Industrial Research Chair in Nuclear Fuel at the Royal Military College of Canada,* was co-authored by W. T. Thompson and Emily Corcoran.


Cathy Cottrell

One final plenary paper was presented on the Wednesday morning by **Cathy Cottrell** of AECL Sheridan Park. Titled *Unique Fuel Cycle Capabilities of CANDU* it provided a broad view of the ability of the CANDU design to accept many variations of fuel from natural uranium, enriched uranium, recycled uranium, thorium, mixed oxides and more. Three workshops have been held on the Natural Uranium Equivalent (NUE) concept, she noted, involving Argentina, China, Japan, Korea and the USA. An added comment to those in the earlier paper of the program she commented that the reprocessing extracts all of the uranium isotopes from U232 to U238 and noted that U234 and U236 act as poisons, which is taken into account when making the final mixture equivalent to natural uranium.

She also spoke briefly about the ongoing program with China on the development of thorium based. CANDU's ability to use various forms of fuel can extend the uranium resource base, she stated in closing.

The technical papers were grouped under the following subject headings:

- Fuel Design
- Fuel Modelling and Computer Code Development (4 sessions)
- Fuel Performance, Reliability and Operating Experience (2 sessions)
- Advanced Fuel Cycles
- Fuel Fabrication
- Spent Fuel Management
- Fuel Safety and Operational Margin Improvement

Beyond the technical sessions there were a number of diversions. At mid-morning on the Monday the delegates crowded onto the large set of stairs from the main floor to the conference level for a group photo, an action that has become a tradition of the Fuel Conferences. Late Monday afternoon there was a tour of the nearby Sir Adam Beck 2 Generating Station, a hydroelectric plant of 1500 MWe capacity.

There were guest speakers at each of the three luncheons included in the program. On the Monday **David Cox**, of AECL Chalk River Laboratories, gave a fascinating illustrated talk on the repair of the NRU reactor. At the Tuesday luncheon **Andy Thorne** of Cameco gave an overview of his company from the mines in northern Saskatchewan to the refinery at Blind River, the conversion plant in Port Hope and the fuel manufacturing facility in Cobourg. On Wednesday, **Dr. Peter Ottensmeyer**, University of Toronto, spoke about the need for fast reactors to burn spent fuel to decrease the amount of radioactive waste while extending the nuclear fuel resource. *(See separate article in this edition.)*


Jerry Hopwood

The conference dinner was held at the top of the Skylon Tower overlooking the entire falls area. **Scott Froebe** of the Organizing Committee served as MC. Guest speaker, **Jerry Hopwood**, AECL Vice President, gave a positive message about the "extraordinary potential" for CANDU fuel, such as the use of uranium from spent LWR fuel and thorium. "CANDU fuel is the fuel of the future", he declared in closing.

The conference was supported by AECL; Cameco; General Electric Canada; Power Workers Union; Stern Laboratories; Kinectrics; Ontario Power Generation; University of Ontario Institute of Technology.

A CD with all of the technical papers will be available from the CNS office.

Gas and wind on the Ontario grid - not a chicken or egg thing

Natural gas or wind, what comes first? How often are we told through the media and via government spin that natural gas-fired generators will back-up wind generation whenever the wind drops. This gives the impression that gas is there solely to support wind. Not true. The Ontario grid depends on dispatchable gas, which is replacing dispatchable coal. Wind is not needed at all as far as grid capacity is concerned. To assign a "capacity factor" to wind generation makes no sense since the grid does not need its capacity. Wind has been added in the belief that periods of wind will reduce the amount of gas being burned and greenhouse gases being emitted. Nuclear and large hydro run base load. Stored water hydro is fully committed to intermediate load (daily load cycling), some operating reserve and to short periods when dispatched in response to grid load changes until other slower generators catch up. This means gas generation, as well as supplying intermediate and peak load, must be dispatched to discretely move power up and down for the longer term grid changes (load following), including those caused by wind, and be quickly available in case the wind drops. The erratic minute to minute fluctuations of wind are smoothed out by grid inertia, by the speed governor action of the fossil generators and by Automatic Generation Control using a small amount of hydro generation. The intermittency of wind is handled by dispatchable gas generation. There will be little, if any, reduction in greenhouse gases and there is no chicken or egg analogy with gas or wind. Gas comes before wind.

Indeed the government plan was to have around 12,000 MW of gas generation available in the next few years, with present gas generation at around 8,000 MW. So, how much wind generation can integrate with 12,000 MW of gas. According to the Independent Electricity System Operator (IESO) the dispatchable range of the Ontario combined cycle gas turbine plants is between 70 and 100 percent full power. Enough gas generation has to be quickly available (depending on the accuracy of the wind forecast) to pick up the slack if the wind drops. Assuming all the 12,000 MW of gas is from combined cycle gas turbine generators (actually there will be some simple cycle gas turbine units for peaking and operating reserve and some combined heat and power plants adding to base load) then if they are operating at the bottom of their dispatchable range they will accommodate 3,600 MW of wind generation, assuming no other make-up like hydro, imports or demand response loads. This amount of wind is more than twice the present operating reserve requirement for the grid. In reality gas generators could be taken down below their dispatchable range to accommodate wind meaning it would take time to get back into the dispatchable range when the wind drops, but hydro and imports may also play a part. Incidentally, according to the IESO, coal has a dispatchable range of 20 to 100 percent which means that if we stick with the roughly 6,000 MW of coal until it can be replaced by an expanded nuclear fleet the grid would be able to integrate 4,800 MW of wind. However since wind and nuclear are a bad mix there would be no point in having any expensive wind with its associated infrastructure. It would not be smart to keep moving the output of multi-billion dollar nuclear plants, producing clean reasonably priced energy, up and down just to accommodate the intermittency of wind. The grid already has about 1,200 MW of wind and 3,500 MW more is expected to be added soon and even more, to a total of over 8,000 MW, when grid connections become available.

Is Ontario being too optimistic with the amount of wind the grid can accommodate to the detriment of grid reliability? Do the government really believe its own spin that wind comes first and will it add more polluting expensive gas generation, whose cost depends on gas price volatility, just to accommodate more megawatts of expensive wind even though gas generation's contribution to the grid would not be needed? Instead of promoting distributed generation (and the so called "smart" grid) using wind and non-renewable gas and oil on the high voltage and low voltage systems wouldn't it make more economic and environmental sense to improve the reliability (improved monitoring of equipment, replacement, refurbishment, redundancy etc) of the present centralized system based on clean nuclear and hydro generation since fossil fuels are going to be scarce and expensive in the future? The operation of the Ontario grid is complex and this is a simplistic perusal but it does raise questions that need to be answered.

Don Jones
Mississauga, ON

[Ed. Note: A larger version of this note can be found at: http://windconcernsontario.wordpress.com/2010/11/20/gas-and-wind-on-the-ontario-grid-not-a-chicken-and-egg-thing/#comments]

Restructuring

by NEIL ALEXANDER, President OCI

At the OCI annual general meeting a couple of weeks ago I outlined a vision that Canadian goods and services should be in every reactor no matter what the type and wherever in the world it is located. An ambitious but achievable goal.

Some of the audience may have jumped to the conclusion that I thought all the industry's effort should be put into integrating our suppliers with the global supply chain. Nothing could be further from the truth. Export sales to light water reactors are certainly an essential part of the overall plan. As an industry we have benefited from being slightly segregated and therefore not under the same competitive pressures faced by other suppliers. That segregation has allowed us to innovate in a protected environment and now we need to use that innovation to our advantage in the developing world market. Some of our companies (L3 MAPPS, SNC Lavalin and B&W come to mind) have been active in doing just that but it is nowhere near as universal as we need it to be if we are to remain as a sustainable entity in an increasingly globalised supply chain.

There is however much more to the plan than a focus on export sales. Extending into these new markets requires that we have sufficient work back home to anchor the industry here in Canada. Without that our capabilities will progressively leach away and the vision will be unachievable. Thus although the long-term vision is expansive the route to it is focused on Canada. The anchor requires two things. Firstly we need to maintain innovation in our own reactor brand, the CANDUs. The successful restructuring of AECL so that CANDUs continue to be built is thus a key part of the long term vision. Secondly we need to continue as a nuclear nation maintaining our proportion of power coming from the nuclear fleet. So New Nuclear at Darlington is an important part of the plan as well. The recent confirmation of nuclear's role in the Ontario supply mix is welcomed but it is the conversion of that into actual projects that is needed.

The ongoing construction of CANDUs is not a slam dunk. Perhaps we think it should be but at the moment it is not.

It is very easy to blame others for this circumstance but even if it is true it does not help. The fact is that we have allowed this situation to develop and we need to turn it around.

The key to doing that is to focus on what is best for the industry. Instead of wasting our energy on finding people to blame let us use our energy to find solutions. Somehow we must put day to day rivalries aside to make our nuclear station operators successful and to assure ourselves of a successful outcome to AECL's restructuring. The refurbishment projects are one very important step on this road and we all need to pull together to make them a success. Our industry associations have the independence needed to help in these issues and we need to trust them to take a lead on bringing the industry together and ensure their independence from individual competitive issues.

Too much of the industry's time has been spent on trying to steal market share from each other. While we have been doing that we have not had our eye on the real ball and that is how Canada can access the world market opportunity.

Perhaps if we can all work constructively together then our politicians might follow our lead. The Province and the Federal Government working in concert could immediately turn, what is an increasingly dire situation, around. Then we will be building new CANDUs in Canada and with a solid home base we can get on with the job of putting Canadian goods and services in to every reactor whatever the design and wherever in the world it is located. Much better we secure 10% of an enormous market than we continue fighting over what could be easily become 100% of nothing.


SIMULATIONS AS REAL AS
THE NEED FOR SAFETY

Nuclear Energy Challenges in this Century

by DANIEL A. MENELEY[1]

*[**Ed. Note:** This paper was presented at the PBNC 17 Conference in Cancun, Mexico on Wednesday, October 27th. The presentation can be viewed at <http://www.pbnc2010.org.mx/conferenceSlides.html> under the heading "Plenary Sessions Presentations".]*

Abstract

The past fifty years have witnessed the advent of a new energy source and the beginning of yet another in the series of energy-use transitions that have marked our history since the start of our technological development. Each of these transitions has been accompanied by adaptive challenges. Each unique set of challenges has been met. Today the world faces the need for another transition. This paper outlines some of the associated challenges that lie ahead of us all, as we adapt to this new and exciting environment. The first step in defining the challenges ahead is to make some form of prediction of the future energy supply and demand during the period. Herein, the future up to 2010 is presumed to include two major events -- first, a decline in the availability and a rise in price of petroleum, and second a need to reduce greenhouse gases in our atmosphere. Both of these events are taken to be imminent. Added to these expected events is the assumption that the total of wind, solar, and other such energy sources will be able to contribute, but only in a relatively small way, to the provision of needed energy to our ever-expanding human population.

1. Introduction

Nuclear energy systems, now more than 50 years old, use a mature technology. They are ready to take on larger and larger roles in the provision of energy for the benefit of mankind. Utilization of this new primary energy source is an engineering task of first magnitude, and is no longer a leading subject of scientific research, except at the margins.

This paper outlines the major tasks remaining for nuclear energy professionals over the next half-century and more. These challenges form an integrated set ranging from the purely technical to abstract questions of sociology and philosophy. They touch on broad matters of public policy as well as on the future development of the world economy.

Today's challenges to the nuclear industry all arise from the known great energy-related challenge to the world; that is, to find a clean and sustainable source of energy to replace petroleum. The only greater related challenge of our day is to find a solution to the problem of world over-population. Without a sufficient energy supply there can be little hope for successfully managing this underlying issue.

Some people say that petroleum is not, and never will become, a commodity in short supply. Better-qualified and convincing persons and organizations point out the error of this thinking. The world now uses approximately 1000 barrels of oil in each second of each year. The latest annual report of the OECD's International Energy Agency states simply "we must leave oil before it leaves us".

This technical challenge to the nuclear industry is indeed very large. Assuming a plant capacity factor of 90 percent, the higher heating value of oil being consumed in the world today is equivalent to the total fission heat produced by about 7000 nuclear units, each with an equivalent electrical capacity of 1 Gigawatt.

At the same time there are other, perhaps greater challenges facing us. Among them is the matter of urgency. We have very little time to meet the main challenge. Using the most optimistic assumptions, the job should be complete before the year 2200. This massive change will require the good will and the effort of many thousands of people, backed by their governments and the population at large.

The following headings address the main challenges ahead of the world nuclear energy enterprise. The opinions addressed herein are completely my own, and make no pretense of being complete. These opinions are drawn, primarily, from Canadian experience but include some broader aspects of the task ahead. Not all of these challenges are important to any single nation; indeed some have already met some of these challenges to some degree.

2. Background

Formulating a list of "challenges" requires, of course, some sort of prediction of the future. This is a notoriously difficult process, and in many circumstances is impossible [1].

In their 2008 report entitled "International Status and Prospects of Nuclear Power" [2] as updated in 2010 [3], the IAEA lists nine key issues and trends, shown in Table I, that constitute challenges for near term development of the nuclear industry. This author prefers to call the first item in Table I a "pre-condition" rather than an issue. Unless the operators of nuclear plants are prepared to operate these plants reliably and safely, they would be wise not to operate them at all, and to find another line of work that is less exacting. Similarly, economic competitiveness is considered a pre-condition, because unless it exists, nuclear energy will not go forward at all.

A more limited prediction was made by the Massachusetts Institute of Technology, as reported in their document "The Future of the Nuclear Fuel Cycle" [4]. The MIT study is focused primarily on the US scene. This report is formulated in terms of findings and recommend-ations. The main points of the Executive Summary have been recast in terms of challenges, in Table II. Several entries are equivalent to those in the IAEA report. The MIT challenge to deploy nuclear capacity at the terawatt scale by mid-century is related to climate change risk in that report. Missing from both of these lists is explicit reference

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Table 1. IAEA Listing of Issues and Trends

SHORT TERM
Safety and Reliability
*Economic Competitiveness and Financing
*Public Perception
Human Resources
*Spent Fuel and Waste Management and Disposal
Transport
Proliferation Risks and Nuclear Security
Infrastructure Building in New Nuclear Countries
*Relationship Between Electricity Grids and Reactor Technology
LONG TERM
*Effective Use of Available Resources
Reactor Design Innovation
Fuel Cycle Innovation
*Updated, 2010

Table II. Challenges Identified in MIT Study

SHORT TERM (ZERO to 40 YEARS)
Mitigation of climate change risk
Global Deployment at Terawatt Scale – LWR Only
+Economic Competitiveness and Financing
+Spent Fuel and Waste Management and Disposal
+Proliferation Risks and Nuclear Security
+Safety and Reliability
Research on Choice of Fuel, Reactor type, and Fuel Cycle
Preserve Options
LONG TERM (40 to 90 YEARS)
+Reactor Design Innovation
+Fuel Cycle Innovations
+Same as IAEA list

to the impending crisis in world petroleum supply.

Given the extremely optimistic assumption that world petroleum demand based on current projections can be satisfied over the next 90 years [5], the predicted growth of nuclear energy capacity (4 percent per year in the "high" scenario) would seem reasonable. However, if a more realistic assumption of oil production

Table III. Expected Challenges Facing Nuclear Industry

SHORT TERM (ZERO to 50 YEARS)
Gain Public Acceptance
Restore Realism to Assessment of Radiation Risk
Complete the Technical Task – Replace Petroleum
Establish the Means for Financing Nuclear Energy Projects
Answer Power Plant Site, Security, Energy Transport Questions
Eliminate Nuclear Weapons Proliferation
LONG TERM (50 to 100 YEARS)
Ensure Commodity Supply and Infrastructure Strength
Grow Nuclear Capacity to More Than Ten Terawatts
Integrate Industrial Systems – Develop "Hydracity" System

had been used then the Terawatt scale of capacity in the world by mid-century would perhaps best apply to the US alone; the world requirement would be about five times larger. This single change in one fundamental *a priori* assumption would drastically change the list of challenges to be faced in the short term.

Prognostications differ. Various experiences and individual assumptions can lead to widely different future scenarios. Without by any means exhausting the possibilities, this paper presents one more set of challenges, underlain by a somewhat different idea of how the future should unfold. Table III, representing this author's predictions, shows a list similar to those of the IAEA and the MIT studies, but with differences. The item first listed in Table III shows what is, in this author's opinion, the most difficult challenge of all.

3. Gain Public Acceptance

Though political systems and practices vary greatly from one nation to another, it is generally true that unless a substantial majority of the population agrees with a major undertaking such as nuclear energy, it will be very difficult to sustain the undertaking over a long period of time. In many countries a vocal minority opposition to nuclear energy has dogged the industry for many years. As the advantages of this energy system become more apparent, this opposition seems now to be decreasing, but this trend could easily reverse if and when a major problem arises in the industry.

In one sense this opposition is useful – it keeps us on our toes. At the same time this active opposition requires a large amount of effort to repeatedly refute the spurious claims of those who are dedicated – some very deeply dedicated – to opposing any activity associated with the adjective "nuclear". The distribution of these zealots is wide. Some can be found entrenched in government bureaucracies and other respected institutions, at times very near to the top levels.

Do we have any "respected institutions" remaining in our society? Hugh Heclo [6], in his book "On Thinking Institutionally" asks us to re-examine our opinions of those institutions on which we rely so heavily, and yet for which we show very little respect. At times, of course, institutions go off the rails and no longer deserve respect – Heclo addresses this phenomenon as well. He illustrates the situation with many examples, and points out that the systematic denigration of our basic institutions has been building up over the past century, to the point that it is now hardly appropriate to support many of them when speaking in polite company.

It must be obvious that our society cannot function without a large number of institutionalized organizations and processes. It is equally obvious that these institutions must earn and hold the respect to the general population. In the case of an operating nuclear utility, this generates a powerful need to deserve the trust of the people from day to day. The same applies to all aspects of our industry, and more so because the integrity of this institution is always under challenge.

"Deserving of trust" is, of course, in the eye of the beholder. Today's political climate of challenge to all institutional authority, coupled with our new instant and worldwide communications pathways, makes it very easy to generate dissent on virtually any topic. The apparent virtues of "truth telling", and the normal penalties for violating that norm, have decreased in recent years. Herein the root cause of our public relations trouble. Perfectly rational people who have a deep understanding of the nuclear industry criticize the industry for not "standing up" to the onslaught, and presenting the true story. A splendid example of such critical remarks can be found at Ted Rockwell's blogsite, [7]. Many of the truths of our industry are defended therein. Others would do well to follow Rockwell's lead. We must do whatever we can to eliminate the falsehoods, the distortions, and the extreme assumptions from our technical discussions.

Over the years of verbal conflict between scientists and engineers versus their opponents, the "defensive ramparts of truth" have become bent and battered to some degree. This is especially so in the area of nuclear regulation, where the technical arguments of the proponents meet the political reality of the day. The regulator must defend each decision to allow a project to proceed with a very high degree of assurance. That institution also is challenged every day, the same as are all the rest of the several institutions involved with nuclear energy. In order to continue this great enterprise of providing the world with plentiful energy, we must remember always to defend the "ramparts of truth" and to rebuild them as and when necessary.

This author considers that the task of providing the necessary human resources to the industry can be included as an integral part of gaining public acceptance of our enterprise. If the people accept the need for nuclear energy, young people will rise to meet that need with enthusiasm and in great numbers. At the same time, if the majority of young people see the wisdom of the choice, the future of nuclear energy will be assured. The only remaining job will be to provide suitable means for their education and training.

The human resourcing task is by no means trivial, since it involves continued re-staffing and training of at least three generations of operating crews for each power plant over its lifetime. The task falls on the operating utility to sustain detailed information about the plant as its configuration changes over decades of operation. This problem is significant in many plants in operation today. Fortunately, modern CADDS systems and training courses used in the original construction phase, modified as the plant configuration slowly changes, will in the future enable the utility to maintain not only the plant, but a detailed model of the plant at any given time [8].

4. Restore Realism to Assessment of Radiation Risk

This challenge is related to the public acceptance challenge, and could greatly assist in reaching that goal. During the original development of nuclear fission reactor technology, a number of very conservative assumptions were made; especially with regard to the health consequences of low radiation doses to people, and also with regard to the potential consequences of reactor accidents. Two major factors have changed. First, the effects of small doses of ionizing radiation are found to be much less than expected, e.g. [9]. Second, more careful analyses based on recent experiments show that the consequence of the "bugbear" accident of pressurized reactors – the large loss of coolant event – has been grossly overestimated in many cases. [10]. Extremely conservative analyses have resulted from years of stringent regulatory review and steadily more demanding criteria of proof.

A direct challenge for the technical community is to eliminate, wherever possible, gross conservatism in safety analysis wherever possible. Though this may turn into a long and painful struggle with regulatory bureaucracy, it may be the best way to regain public confidence, in the end. Perhaps the most important example of unjustified extreme conservatism is the almost universal application of the now discredited linear, non-threshold hypothesis for estimating the consequence of low radiation doses to large populations. A growing array of facts drawn from past experience [7] suggests that re-evaluation is required of many of our present-day licensing analyses in the light of improved engineering knowledge and operating experience.

5. Complete the Technical Task – Replace Petroleum

Electricity supply is only one of the tasks that soon will be required of nuclear generation systems. Petroleum, one of the world's major enabling resources will almost surely rise dramatically in price within this century, but may even become a scarce resource, at least in some parts of the world.

5.1 The Need

There is still some debate regarding the timing, and even the existence, of the "peak oil" phenomenon, the postulate that we are at or near the maximum production rate of petroleum. Recent price fluctuations support this postulate – fluctuating price is seen in many cases when a commodity in demand approaches its maximum production rate. Exploration plays are now rare outside areas controlled by national oil companies, and tend toward deep offshore ventures that are very expensive. Unconventional reserves such as oil sands bring with them high development and production costs that demand higher product prices.

In their latest annual report, the International Energy Agency of the OECD [5] strongly reminds its member nations:

> "One day we will run out of oil, it is not today or tomorrow, but one day we will run out of oil and we have to leave oil before oil leaves us, and we have to prepare ourselves for that day. The earlier we start, the better, because all of our economic and social system is based on oil, so to change from that will take a lot of time and a lot of money and we should take this issue very seriously".

At the same time the world can take comfort in the fact that there is enough nuclear fuel available to supply us with energy for thousands of years. Once again we are fortunate to have "A bird in the hand" in the form of today's mature nuclear technology. Our descendants may well invent a better way to meet this need – but just in case they do not, we know that nuclear fission energy can do the job. Even though a diverse suite of alternative sources likely will persist over time in niche markets, nuclear energy must provide the bulk of the world's supply for a very long time. We must do the heavy lifting!

The latest issue of the IEA report presents a sobering picture in their reference scenario, which follows the expected trajectory of world energy development over the next 20 years, assuming that world governments make no changes to their existing policies and measures for energy supply. This scenario is dominated by large increases in demand for fossil fuels, extensive exploration, and consequent large capital requirements. The expected total investment requirement is 26 trillion US dollars up to 2030. The power sector requires 53% of this total. The IEA report [5] concludes that:

> **"Continuing on today's energy path, without any change in government policy, would mean rapidly increasing dependence on fossil fuels, with alarming consequences for climate change and energy security."**

For the past several years the IEA has urged OECD governments to increase their commitment to nuclear energy. Most countries of the world show signs of taking up this challenge, with the surprising exception of the OECD countries themselves. In both Europe and North America the response is half-hearted at best, up to now. The IEA report notes the following:

> "The main driver of demand for coal and gas is the inexorable growth in energy needs for power generation. World electricity demand is projected to grow at an annual rate of 2.5% to 2030. Over 80% of the growth takes place in non-OECD countries. Globally, additions to power-generation capacity total 4,800 gigawatts by 2030 – almost five times the existing capacity of the United States. The largest additions (around 28% of the total) occur in China. Coal remains the backbone fuel of the power sector, its share of the global generation mix rising by three percentage points to 44% in 2030. Nuclear power grows in all major regions ***bar Europe***, but its share in total generation falls."

The underlying driver of this demand growth usually is, of course, the rise in world population – energy demand growth is a consequence of this seemingly uncontrollable factor. At the present time, however, it seems that much growth arises from the need (or at least the desire) of underdeveloped countries to increase their standard of living. Any energy policy must be coupled with stabilization of the world population along with rising living standards. A sustainable level of energy supply is a necessary prerequisite if we are to provide a respectable living standard for all people.

5.2 Meeting the need

In its 2009-2030 alternative (preferred) scenario, called the "450 Scenario", so named to indicate a target of 450 parts per million concentration of carbon dioxide in the atmosphere, the IEA Executive Summary for 2009 points out:

> "Power generation accounts for more than two-thirds of the savings (of which 40% results from lower electricity demand). There is a big shift in the mix of fuels and technologies: coal-based generation is reduced by half, compared with the Reference Scenario in 2030, while nuclear power and [*other*] renewable energy sources make much bigger contributions."

Three points are notable in this statement. First, I have inserted the word "other" in square brackets to emphasize the now-recognized fact that nuclear fuels are sustainable for many thousands of years [11], so this energy source should be included in the "renewable" category. Second, the hoped-for amount of demand reduction due to conservation in the electricity sector is very large – a most optimistic projection, given past experience. The third item of note is the urgency of action to reduce our reliance on petroleum. There is very little time left for our world to adapt to the coming collapse of the present-day environment in which petroleum is relatively plentiful and cheap. It is quite apparent that someone will repay the tens of trillions of dollars that must be invested in oil supply development to ensure supply of oil up to 2030. It also leaves a big question as to what we might expect to happen during the following quarter-century. For a rather gloomy guesstimate of the upcoming situation, see the apocalyptic prediction in the book "The Long Emergency" [12].

Accepting the IEA estimate of "new build" generation capacity requirements up to 2030, and then assuming that all of these new plants will be powered by uranium, we **would** need to build 240 nuclear units each of capacity 1 gigawatt every year between now and 2030. This ideal situation will not be realized, of course, but the number certainly provides a "stretch" target for new nuclear plant construction. Once again, with reference to the IEA alternative scenario, there is another challenge implied -- the provision of transportation fuels. This most important topic is outlined in subsection 5.3.

Where else could we get this massive energy supply? Dr. Charles Till, retired Associate Director of Argonne National Laboratory [13] reaches the following conclusion:

> "To sum up, the alternatives to fossil fuels are very, very few that could promise the magnitude of energy required to meet our nation's need. It is not as though plentiful alternatives exist, and one can be weighed against another …"
>
> "The blunt fact is that there are the fossil fuels and there is nuclear."

> "Failure to recognize this, while focusing on options that do not and cannot have the magnitudes [of supply] required, will inevitably lead to increasingly dangerous energy shortages. Who then will answer? Will [it be] the environmental activist, who blocks real options, and then puts forth options that cannot meet the need?"

Who else indeed? Will it be the politician who is ready to subsidize unsustainable short-term solutions and who forever plans for his re-election, carefully deferring difficult decisions until after that happy day? Not likely.

My expectation is that the engineer will answer, based on past history. More generally, it is the organization that people really expect to deliver the goods – usually the electrical utility or other operating organization. Because of the long time taken for the results of these decisions and their consequent good or bad impact on society to be revealed, politicians usually get away with no need to answer to anyone.

From the point of view of a large-scale enterprise, the uranium industry exhibits characteristics similar to both the oil industry and coal industry. The time scales involved in exploration, development and market delivery times are all very much longer than political cycles. They all require enlightened and consistent public policy over a period of decades to enable them to become effective. Only real statesmen can and do listen to recommendations whose consequences lie further in the future than the next round of the electoral cycle.

To answer the need for sustainable large-scale energy supply, the first step is to examine the available options. Among the options that are concentrated and thereby easily collected, by far the largest energy potential is from coal or uranium [14] Figure 1, pg. 6. Figure 2 in the same document compares nuclear and coal. Wind is included in the Figure only to show the best of the diffuse options – and the most popular today. Its primary disadvantage is its highly variable nature, which must be backed up by either backup sources or by major energy storage facilities.

Coal suffers from an extraction rate limit and an uneven distribution of deposits, thereby causing transportation difficulty in many nations. Nuclear fission energy is the clear choice. It is highly concentrated and so has only minor transportation problems for either fresh fuel or for used fuel. In addition, this fuel is inexhaustible [11].

The very large quantities of fuel available from uranium and thorium are well known [14] Figure 3, page 7. Using today's technology (thermal reactors) along with the 2005 total world energy usage, we see that at least 40 years of fuel supply are assured. Assuming a reasonable rate of exploration and tolerable increases in fuel price, at least 300 years of fuel supply can be assured from uranium resources alone. Accounting for thorium fuel supply would probably double the amount shown in this Figure.

Fast reactors apparently are necessary to extend nuclear fuel availability in time, to well beyond the horizon of human existence. It is not practical to mine uranium from seawater to fuel thermal reactors, because of the very large required extraction rate. Fast reactors do not suffer from this drawback, however, because a one-gigawatt electric unit requires only 2 tons of makeup uranium per year. This makeup fuel also can be obtained from dilute ore deposits, from the ocean, or from depleted uranium from enrichment plants. This huge diversity of fuel sources arises because of the very large amount of potential energy in each unit of natural uranium or thorium.

5.3 Alternative strategies

The world is, at the present time, blessed with a sound cadre of successful nuclear plant designs. Based on direct experience, these designs are seen to be economical, safe and reliable when properly managed and regulated.

The basic choice, then is whether to build a large fleet of existing plant designs (subject, of course, to the slow evolution in detail that always follows from experience) or to re-examine all of the alternatives previously studied, so as to find one or more optimum designs for the future. Based on this author's understanding of the great urgency of building to replace petroleum as its supply declines and its price rises, it is recommended that the correct path can be found closer to the first option than the second. This is mainly due to the urgency of our situation – it is imperative to begin building a large number of power plants now. We have no time to waste. We have no time for long, drawn-out research programs. In this case, in a very real sense "the perfect is the enemy of the good".

Edward Kee, Vice President, NERA Economic Consultants, said in a recent interview [15] that, from the point of view of both vendor and buyer,

> "The most important issue for reactor designs is to get a lot of units built and in operation as fast as possible. This gets the design down the learning curve to lower costs and shorter schedules, but also stimulates additional sales from buyers who look for low risk and demonstrated success. While design features are important, market success is much more important."

This market reality strongly discourages introduction of revolutionary design concepts, especially if private industry is expected to shoulder the majority of project risk. Of course there is no reason that the development of improved or new designs cannot continue in parallel. It must only be assured that any development effort does not interfere with the ongoing production plant capacity buildup.

Existing plant designs can be operated with adequate safety, if they employ conscientious crews led by knowledgeable and "mindful" management [16]. Meeting the need for energy immediately creates the challenge of supplying trained manpower to build and operate the plants. Fortunately, this need is fully recognized within the industry.

Given the fact that thermal reactors must be built in large numbers as soon as possible, the question arises as to which characteristics of these units will ease the transition to new designs when they are available? It is obvious that the transition will begin only when the price of uranium rises; it is also obvious that any new reactor type must have improved characteristics for uranium utilization; preferably, these reactors should produce more fissile material than they consume. Their excess fissile material then could be blended with recycled materials to refuel thermal reactors without using any new uranium. The effect of this strategy will be to control the rising price of natural uranium. The best available system for this purpose is the fast reactor design known as the Integral Fast Reactor, or IFR [17].

Clearly, during the transition between thermal and fast reactor fleets, the less excess fissile material required for refueling of existing thermal reactors, the greater the flexibility for growing the numbers of fast reactors. This indicates that the best strategy to prepare for this transition is a thermal reactor fleet with a high ratio of fissile material produced per unit of fissile material consumed – usually called the "conversion ratio". Commitment of "High-C" thermal reactors such as the PHWR today would considerably ease the future transition toward a mixed fleet of thermal and fast reactors [18].

Nuclear energy also can be used to reduce petroleum use for transportation fuels. For example, the following conclusion is quoted from a recent paper [19]. These concepts are explored further in a later work [20].

> "Liquid fuel demands for transport could be reduced in half by combinations of several options such as diesel engines and plug-in hybrids. Independently, the biomass liquid fuel options could meet existing liquid fuel demands without reductions in oil demand. Rapid technological changes are occurring with the development of biological plants for fuel production, methods to process biomass, and plug-in hybrid vehicles, as well as in other areas. Consequently, the specific combination of biomass, nuclear energy, and liquid fuels for transportation will be determined by the results of this development work."

A great deal of work is now being done in this field. There is a high expectation of success. As a direct result, requirements for additional nuclear capacity might well arise over the next few decades. Nuclear capacity planners should consider this possibility very seriously.

6. Establish means of financing large-scale nuclear energy

Financing is difficult for large projects such as nuclear plants. Two good comparisons are seen in development of a new oil field and the construction of a continental highway network. In the first case large capital resources must be committed many years before any return can be expected. In the second case, people expect that taxpayers will fund major highway construction.

Bill Gates [21] puts forward a precise and simple explanation of the problems of nuclear plant finance. He argues that the private sector will remain unable to finance this new build program, but that governments can help a great deal. The US government has, in fact, begun this process by offering loan guarantees. A similar system was utilized to finance construction of the Qinshan-3 project in China; nations associated with several major systems and components used export development loans of various kinds. This operation was very successful, and the loans are now being paid back expeditiously.

Government loan guarantees could be established in support of the project. Loans would be repaid over time during plant operation. Financing also would be greatly eased if some of the capital expenditures incurred during plant construction could be charged into the rate base, recognizing that plant benefits will eventually accrue largely to those same ratepayers. Both of these alternatives depend completely on the support of the community where the plant is located, thus underlying the paramount importance of their trust that the plant being constructed is truly in their interest. Of course, this is a political and sociological question.

The complexity and uniqueness of project arrangements for building a large plant defeat any attempt to generalize the process. There is no doubt that it is one of the crucial steps toward success. Expert management combined with careful project planning, clear definition of roles and goals, along with comprehensive design and scheduling of each step of the project can lead to timely and economical project completion [8}.

Financing of large projects can benefit from better predictability; this can be achieved through standardizing all or even part of any plant design. Partial standardization implies modularity, and is the preferred alternative recognizing the large span of time involved between projects that might be built on one site as well as the wide diversity of site conditions, in other cases. In most situations it is be wise to restrict evolutionary design changes to infrequent, incremental steps.

All of these arguments support standardized design for new plants and militate against radical changes, even though such changes might be advantageous in theory. In general, such developments must take place outside normal commercial venues. New reactor types must be thoroughly tested and demonstrated before being considered seriously as production options.

7. Answer power plant site, security, and energy transport questions

Assuming the greatly increased scale of this industry, choice of sites for new power plants will become a serious issue in the future. As the application of nuclear energy broadens from electricity production into a wide range of industries [22] it may be necessary to update traditional thinking about these locations. In any case, the area requirements for the plants themselves will not be large; the majority of space will be required to accommodate the "industrial parks" that will surround these plants.

The need for security is another factor in the choice of site. Together, these two factors suggest the establishment of energy parks on which many nuclear units (at least, those of a scale envisaged today) will be co-located along with fuel recycling and possibly long-term fuel storage facilities. Recycling "on site" may well be preferred to drastically reduce the need for shipping of used fuel and other radioactive materials back and forth to the power plants. High security for all nuclear materials is, of course, easier to establish on a large site than it is on a number of small, isolated sites.

Yet another advantage of energy parks is that they can service smaller sites without the need or the capability to grow very large [23]. The so-called "hub and spoke" arrangement is very likely to be chosen in most cases. The idea is that small or medium capacity (SMR) units would receive their fuel from an energy park, and return their used fuel to the energy park for recycling. Several of these satellite units serviced by a single large central site.

Presuming that a few large-scale sites are established raises the question regarding the proper scale of nuclear units to be installed there [24] Those studies indicated that very large (5,000 to 10,000 MWe equivalent) units could be optimal. Industrial application also likely will lead to some of the units being dedicated to supply process heat; these may or may not include electrical generation capability.

When established these energy parks would be similar to large oilfields in production capacity. Their main energy currencies [25] would be electricity and hydrogen; this system could be identified by the newly coined word "hydricity". Transportation fuels may be an important product, carried from the site to consumers via conventional pipelines or supertankers. Location of energy parks on large waterways, ocean shorelines or islands would greatly facilitate transport of products from these sites.

8. Eliminate nuclear weapons proliferation

This issue is really one that must be solved through international diplomacy; technical methods can assist in reaching the goal of eliminating both national and sub-national weapons production; however, in the end it is a matter that must be settled through international agreements. As noted in the book "The Bottom Billion" [26], behavior of individuals and nations is more effectively sustained through social "norms" rather than laws or coercion. Agreements between governments establish these norms of behavior. The nuclear non-proliferation regime constitutes the sum of these agreements. Up to the present day, this network of agreements has been sufficient to avoid any use of these weapons. As technology advances and behavioral norms are even better established, it is reasonable to hope that the use of all weapons of mass destruction, including this one, will be eliminated.

9. Ensure commodity supply and infrastructure strength

By this time (about 50 or so years into the future) one possible issue will be the supply of the necessary materials and equipment to serve an ever-growing population. The underlying issue is, of course, the sustainable limit of human population. Otherwise, just how many people constitute a "full house" on this earth?

Note that two of the IAEA issues do not appear in the present list: reactor design and fuel cycle innovation. This author assumes that these aspects of nuclear energy development will occur more or less automatically as the promised capacity of the system increases. I assume that they will be driven by a combination of human need and commercial enterprise. This is not to say that they are unimportant, but only to recognize that the form and style of these developments will be a matter of trial, error, and discovery.

Fuel supply is one aspect of long-term development that is already established. Several publications e.g. [11], [27], confirm this, provided only that systems capable of transforming almost all of the fertile material into fissile fuel are installed. The Integral Fast Reactor [17] has already demonstrated this basic capability.

10. Grow nuclear capacity to more than ten terawatts (equivalent)

This figure for ultimate nuclear capacity can only be a wild guess. It is intended to indicate a large number, and one that could include not only electricity generation but also a broad array of industrial processes [14]. Ten thousand one-gigawatt units (electricity equivalent) seems to be a large number, but the actual unit capacity will likely be considerably larger by this time.

When the world's nuclear energy system has grown to approximately this scale, it will be capable of supplying all of the energy needs of humanity for thousands of years. Of course, a better way of supplying large amounts of safe and reliable energy may be invented before this time, even though none is apparent on the horizon at this time.

11. Conclusion

The era of cheap and abundant petroleum and natural gas is drawing to a close. Many alternative replacements are proposed. The only clear alternative today is nuclear energy extracted from uranium and thorium. During the past seventy years, this new energy source has been fully developed and installed as a second-rank contributor to the world's energy supply. During the next 50 to 100 years it can and will grow to become a predominant force in sustaining the health and well being of all humanity. If necessary, fission energy can continue this role for many millennia.

No prediction of the future can be reliable, and this prediction is no exception to the rule. By studying our energy supply options we can only hope to improve our understanding of the present, and thereby might improve our descendants' chances of survival in the future.

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An Alternative Perspective

Used Nuclear Fuel Waste: A $36 Trillion Energy Resource

by PETER OTTENSMEYER

[Ed. Note: Dr. Ottensmeyer is Professor Emeritus at the University of Toronto. A brief biography appears at the end of this article.]

The World's nuclear fuel waste, including Canada's 40,000 tons of used CANDU fuel, is slated to be sequestered in deep geologic repositories, in general permanently. This used fuel contains an enormous amount of energy that can be tapped using fast-neutron reactor facilities. In Canada the currently stored used nuclear fuel would create $36 trillion of carbon-free electricity in fast-neutron reactors while its long-term radioactive burden would at the same time be reduced 100,000-fold. Even the resulting fission products would become an accessible source of rhodium, palladium and rare earths worth over $100 billion.

Introduction

The World's nuclear nations are on course with a disposal plan for nuclear waste that will discard a gargantuan resource of carbon-free energy and in Canada throw away $1 million for every Canadian. This resource by itself in Canada is large enough to produce energy for the entire country for close to a thousand years, yet create no greenhouse gases. This resource is used nuclear fuel.

Used nuclear fuel waste has been an Achilles heel of nuclear energy in the perception of the general populations of all nuclear nations. While the volumes of such used fuel are relatively small, the very long radioactive half-lives of the constituent transuranic actinides and several fission products (FPs) created in the reactors have raised a spectre of imminent and future radioactive contamination after a potential breach of containment.

The solution adopted virtually universally is the incipient placement of such waste in deep geologic repositories (DGRs), eventually permanently. The culmination of Canadian plans [1], which formally began with the Hare Report in 1977 [2], and now follow the primary requirements of the *Nuclear Fuel Waste Act* of 2002 [3], was well presented by Hunt in the previous CNS Bulletin [4].

If one considers the enormous energy content of used nuclear fuel, it seems utterly reckless for Canada, or the World, to discard such riches in a DGR rather than to use them.

There is a very positive alternative: a fast-neutron reactor facility to consume the waste, massively reduce its radioactive burden and create vast quantities of carbon-free energy in the process. This too is in the purview of the *Nuclear Fuel Waste Act*.

In Canada in 2008, CANDU reactors produced $9 billion of electricity from 1,400 tons of natural uranium [5], using up less than one percent of the uranium. The remaining 99% is considered spent fuel, waste. This same uranium waste, consumed completely, along with the 40,000 tons of such waste in storage from previous years of power production, would produce $36 trillion of carbon-free electricity and at the same time reduce the long-term radiotoxicity of the waste nearly 100,000-fold.

One can do this today, with fast neutrons.

Fast-Neutron Reactors

CANDU reactors, like all thermal reactors, use slow neutrons, which cannot extract energy from the largest portion of natural uranium, the 99.3% that consists of uranium-238. However, in reactors using fast neutrons the 99.3% uranium-238 can also be consumed. As an added advantage, fast neutrons destroy the transuranic actinides (TRUs) in the spent fuel, the neptunium, plutonium, americium atoms, etc., that are major concerns in nuclear fuel waste because they remain radioactive for many thousands of years. With fast-neutron reactors the result of consuming all actinides is a 100,000-fold reduction in long-term radiotoxicity of nuclear fuel wastes (see below).

Canada has no fast-neutron reactors. We need to build one.

Fast-neutron reactors (FNRs), primarily with sodium cooling, have been built for research and, in Russia, for commercial energy production. Outputs have ranged from 200 kWe (US EBR-I) to 560 MWe (Russian BN-600). A larger Russian commercial FNR, the 880 MWe BN-800, is under construction, with a further two planned for China. Historically, the very first nuclear-generated electricity was created using heat from an FNR, the EBR-I, on December 21, 1951 at the Argonne National Laboratories in Idaho. Among these power plants the best reactor to emulate is the American 20 MW experimental EBR-II, which operated flawlessly from 1964 to 1994. It provided the most extensive information relevant to safety and to utilizing nuclear fuel waste [6,7].

In the most telling safety tests, EBR-II operators deliberately implemented the scenarios that led to the Three-Mile-Island incident in Pennsylvania and to the Chernobyl disaster in the Ukraine. The reactor shut itself down without human or automated intervention, even with intentionally deactivated safety control rods. Its physical design properties made it passively safe [6].

Fuel Consumption

Most fast-neutron reactors use up about 10% of the fuel before refueling. This, however, is not a fundamental limit.

Experiments in the EBR-II on fuel usage improved consumption from an initial 1 – 3 percent to 18 percent, not by changing the reactor, but by successive redesigns of the fuel canister [7]. An initial 100% fuel fill resulted in canister failure at around 5% fuel "burn-up" due to swelling of the solid metal fuel as FPs were formed. This problem was eliminated by a reduction in fuel fill to 75%, to accommodate the swelling. Failure of the container then occurred at a higher fuel "burn-up" due to rupture from the internal pressure created by gaseous FPs. Further improvements resulted from changing the container material from 316 stainless steel to the stronger ferritic/martensitic HT9. The last refinement, a 75% fill plus a plenum, or empty space, in the canister equal to 0.7 of the fuel volume for gaseous expansion, resulted in a safe 18% fuel consumption. Failure from rupture did not occur below a burn-up of around 23 – 25 percent.

When the EBR-II was shut down in 1994, the US fuel experiments continued in the Phenix FNR in France, in 2007 achieving a designed safe burn-up of 25 percent in a canister with a plenum equal to twice the fuel volume [8]. The failure limit was not tested.

For consuming used nuclear fuel waste, higher fuel usage before refueling would be of benefit to reduce handling and recycling of the used fuel as much as possible. Data on fuel consumption higher than the 25% above appear to be classified, if they exist; but calculations have been made below.

Calculated limits to fuel consumption

Build-up of fission products in the fuel restricts the useful fuel burn-up in CANDU reactors to about 0.75%, with FPs eventually absorbing too many neutrons to allow the chain reaction of neutron production, with concomitant energy production, to continue. In contrast, the above experiments in the EBR-II and Phenix FNRs show that even at a burn-up of 23%, when fuel canister breach occurred from internal gaseous pressure, it was the fuel container design that was limiting rather than excessive neutron absorption by the FPs.

How high would fuel consumption of used CANDU fuel be in an FNR with an ideal fuel container design? The quick answer (see below) is 35%, derived from calculations using available practical reactor design parameters and fundamental physics cross-sections for neutron scattering.

Figures 1 and 2 show the results of combining the design parameters from the General Electric/Hitachi sPRISM FNR, based on the EBR-II concept, with the neutron cross-sections for elastic scatter, inelastic scatter, radiative capture, and fission [9-11]. In Figure 1 the relative neutron absorption contributions from the major fuel components are shown at initial neutron equilibrium. The initial fuel charge consisted of used CANDU fuel enriched with about 9% uranium-235 (alternatively about 7% plutonium-239 was used for the data in Figure 2). All FNRs require fissile enrichment for a catalytic start, but maintain that fissile component as other actinides are used up. Only the high-energy region is depicted in Figure 1, since in FNRs very few fast neutrons created by a fission event survive to lower energies, with virtually none reaching thermal energies.

The consumption of uranium-238 in used CANDU fuel and the build-up of FPs is shown for five refueling cycles in Figure 2a. In a single pass about 50% of the U-238, and corresponding amounts of other actinides would consumed (once-through, dotted lines extensions in Figs. 2a and 2b). However, the reactor would lose power towards the end of such fuel utilization and also use up some of the enriched fissile material (e.g. Pu-239, dotted line in Fig.2b). If a constant power output is to be maintained, then refueling has to occur at a level of about 35% uranium-238 use.

At this 35% point the fuel assemblies need to be removed, either individually if full-power fueling is part of the design, or altogether. The FPs are extracted, and the remaining unseparated

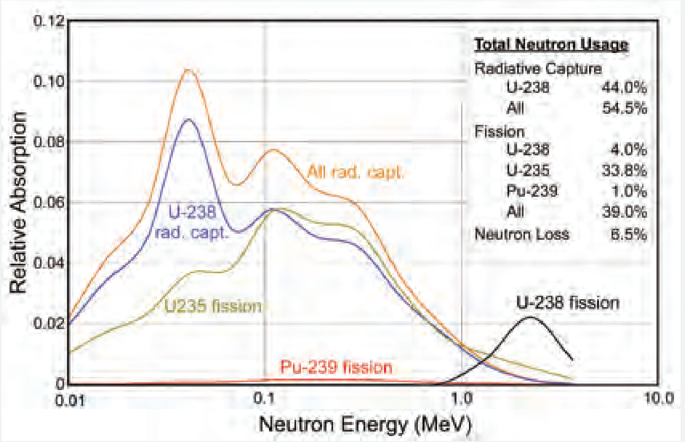


Figure 1: Energy distribution of the relative fission and radiative absorption characteristics of fast neutrons in key fuel isotopes for a representative sodium-cooled fast-neutron reactor.

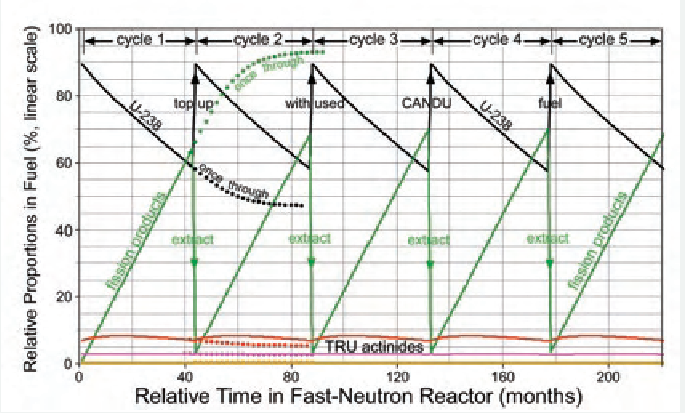
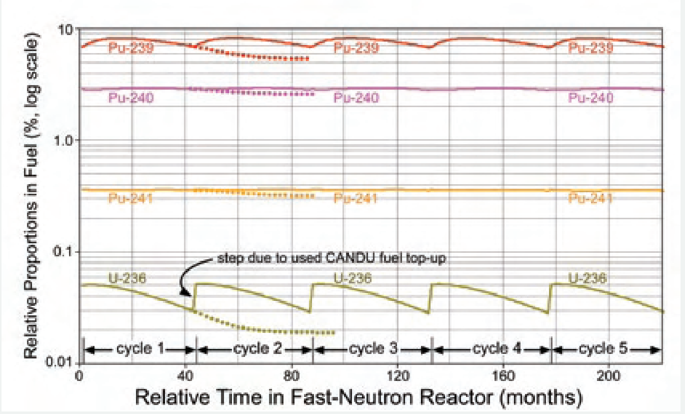


Figure 2: (a, top) Relative concentrations of uranium-238 and fission products as a function of time in a fast-neutron reactor. The dotted lines indicate the time development if refueling does not take place (see text). The levels of TRUs are shown at an expanded scale in (b).
(b, bottom) Relative concentrations of representative TRUs and U-236 as a function of time in a fast-neutron reactor. Note the semi-log scales to depict the large range in concentrations.



actinides are returned to the reactor. Since the fuel charge is now only 65% of the initial fuel loading, the fuel is topped back up to

100% with used CANDU fuel. No additional fissile enrichment is required, since sufficient fissile material remains in the unseparated actinides. This refueling point would constitute the end of one fueling cycle. The cycle would repeat for the life of the reactor.

The cyclic behaviour of the concentration for some of the other actinides is shown in Figure 2b. During any single cycle, Pu-239 levels would increase a few percent, only to return to their starting concentration at the end of the cycle. A similar behaviour is seen for the other TRU isotopes and for U-236. Thus from cycle to cycle, the concentration of all of the actinides in the reactor, including the more fissile components, remains constant.

The consequence of this cyclic behaviour is that all of the actinides in each 35% top-up load of used CANDU fuel are completely consumed and converted to FPs. Furthermore, the process completely extracts the energy in all of the actinides in the top-up load of used CANDU fuel, not merely the 1% or less that is accessible in thermal reactors. Thus in three cycles one "reactor-full" of fuel waste would be consumed and one reactor-worth of TRUs eliminated.

Recycling

The extraction of fission products at the end of each fuel cycle is an important component of refueling.

The reactor can easily function even with a 5 – 10 percent residue of FPs in the recovered fuel. However, for the FPs to become exploitable in future they must be sufficiently free of long-lived actinides.

The most promising approach to achieve such purification of FPs is pyrometallugical processing. This procedure, an electrochemical process in molten salts at high temperatures, has been studied for actinides by Laidler et al. [12] as part of the Argonne National Laboratory program for an Integrated Fast Reactor, a similar concept as proposed here but aimed primarily at fuel recovery. The process can extract 99.9% of the actinides without separating individual actinide elements [9]. Conversely these results indicate that only 0.1% of the actinides remain with the FPs. Only a further 100-fold purification would be required to reduce radioactivity of the actinides among the FPs to natural background levels. This could be readily achieved by subsequent recrystallization, and zone-refining. Zone-refining routinely achieves purifications of one part in a million for silicon in the semiconductor industry or aluminum in metallurgy, more than sufficient for FP purification. In addition, the natural decay of Pu-241, one the TRUs, would reduce the radioactivity in any remaining actinide impurities by a further 70 times in less than 100 years.

100,000-Fold Reduction in Long-Term Radioactivity

Figure 3 illustrates the radioactive decay of used CANDU fuel after it leaves the reactor. The curves for FPs and for actinides are shown in relation to natural uranium. The use of fast-neutron reactors would eliminate the actinides, removing the TRU curve from the graph as well as the uranium line. The impact of this is a 100,000-fold reduction in long term radioactive burden of the resulting "waste", equal to the integral of the area between the two curves from the 200-year to the 400,000-year points. (Note that

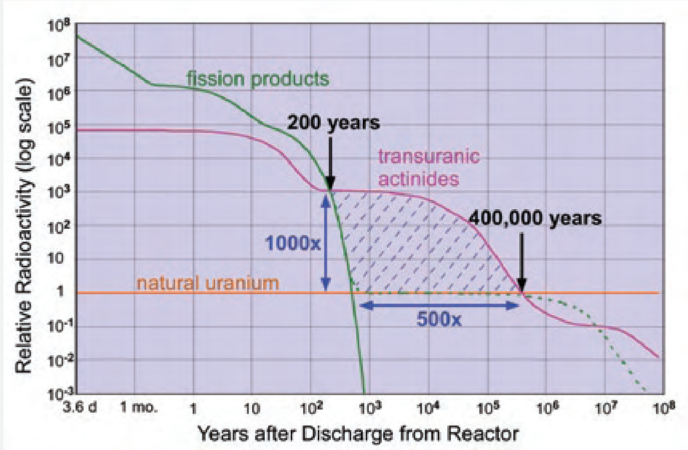


Figure 3: Radioactivity versus Time for Spent CANDU Fuel with a 0.74% Fission Product Content. Fission products with shorter half-life (solid green line), with long half-life tail (dashed green line). Blue-hatched area represents reduction in long-term radioactivity and in half-life of the bulk of fission products, achievable with a fast-neutron approach.

the log-log representation visually distorts the size of this area).

The fission products remain; of these, 30% are radioactive. However, the half-life of this residue is close to 500 times shorter than that of used CANDU fuel, with most isotopes reaching a natural background level in 300 years or less. Four atoms, iodine-129, cesium-135, zirconium-93, and technetium-99, are radioactive much longer, but emit only electrons with energies so low that they are easily stopped by a barrier of clear plastic only two millimeters thin.

Surprisingly, many atoms among the 40,000 tons of FPs resulting from the consumption of used fuel waste, like rhodium, rubidium, and rare earth atoms, are quite valuable. At current prices the fission product elements would fetch over $100 billion. A 300-year safe storage for them would therefore be appropriate, since after that wait these mineral "riches" would be extractable by ordinary means.

The Way Forward

There are many advantages to the fast-neutron approach of nuclear waste management, with long-term energy security and greenhouse-gas elimination being two obvious benefits. More immediately, electricity worth $36 trillion, minerals worth $100 billion, and a 100,000-fold reduction in long-term radiotoxicity, is clearly a legacy well worth pursuing.

The Canadian *Nuclear Fuel Waste Act* [3] permits this path, although it stipulates international cooperation. Section 20 (2) of the *Act* states: "*If a new technological method is developed that has been the subject of a scientific and technical review by experts from international governmental organizations that deal with nuclear matters and has received their support, the waste management organization* [NWMO, auth.] *may propose, in its triennial report, a new approach for the management of nuclear fuel waste that is based on that new method.*"

Canada, a bold leader in the past with the peaceful use of nuclear energy, can also lead in the productive elimination of nuclear fuel waste. This course, which brings with it an enormous carbon-free energy output, would create a solid economic base of constant dependable and green electricity for homes, industry and transportation, firmly underpinning solar, wind and other environmentally sound technologies. Alone, or jointly with the Americans, Japanese, French and Russians, who have already used FNRs for carbon-free power, Canada can and should show the way by constructing nuclear-waste-eliminating fast-neutron reactor facilities today.

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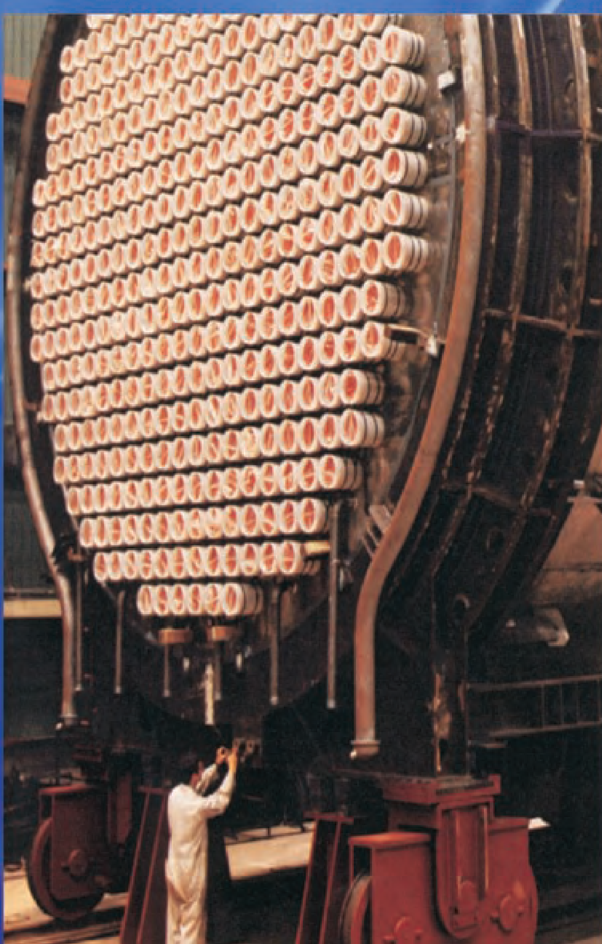
Professor Ottensmeyer has a BASc in Engineering Physics (metallurgy), an MA in Solid State Physics, and a PhD in Medical Biophysics. He has worked on the design and construction of electron spectrometers and their use in microanalysis and has spent most of his career in its application to cancer research. He was surrounded by giants in the field such as Harold Johns, who developed the cobalt-60 radiation treatment of tumors. That in turn probably led to his interest in nuclear waste disposal …



GENERAL news

(Compiled by Fred Boyd from open sources)

New Ontario Energy Plan Continues Nuclear Role

In the report *"Ontario's Long Term Energy Plan"* released by the Ontario Ministries of Energy and Infrastructure on 23 November 2010, nuclear is proposed to continue to be 50 per cent of the electricity generation capacity of the province.

Despite the title the report is entirely about Ontario's electricity system and is focussed primarily on demand and supply.

To quote from the report:

Ontario will continue to rely on nuclear power – at its current level of contribution to the supply. Nuclear generation is ideally suited for providing baseload generation because of its unique economic and operating characteristics. A generation mix of 50 per cent nuclear combined with baseload hydroelectric generation is sufficient to meet most of Ontario's baseload requirements.

If nuclear capacity beyond this were added, the hours in the year in which nuclear capability exceeded Ontario demand could substantially increase. Under such surplus conditions, some nuclear units might need to be shut down or operate differently than intended. This could lead to significant system and operating challenges and therefore, generating too much nuclear is undesirable.

The report goes on to say:

Over the first 10 to 15 years of this Plan, 10,000 MW of existing nuclear capacity will be refurbished. Investment should focus first and foremost on the improvement of existing assets so that those facilities can continue to provide reliable, affordable electricity. A coordinated refurbishment schedule was agreed to in 2009 by a working group including OPG, Bruce Power, the OPA and the Ministry of Energy.

The government is committed to continuing to use nuclear for about 50 per cent of Ontario's energy supply — a capacity of 12,000 MW will produce that amount of energy. The remaining nuclear capacity of 10,000 MW at Darlington and Bruce will need to be refurbished and modernized.

The remainder of the nuclear capacity that Ontario will need for its projected demand (about 2,000 MW) will be made up of new nuclear at Darlington.

The report makes some pointed comments about the federal government's decision to sell Atomic Energy of Canada Limited, as follows:

In February 2008, the government of Ontario launched a process to procure two new units at the Darlington site. AECL emerged as the only compliant bidder in the process; however the AECL bid price exceeded the province's target. Ontario then sought to finalize a deal with the company to procure the units at an acceptable price.

During the discussions between the Ontario government and the federal government, the federal government announced its intention to sell AECL in May 2009. The position of uncertainty that the federal government placed AECL in, together with a much higher than anticipated price, made it very difficult for Ontario to finalize a procurement that was in the best interest of ratepayers. As a result, Ontario suspended the RFP process in June 2009.

The Premier of Ontario wrote to the Prime Minister requesting that the process to sell AECL be halted. It was Ontario's position that both levels of government should try to complete the procurement with AECL before the company was sold so that Ontario's need for significant nuclear refurbishment and new nuclear generation could be met while simultaneously protecting jobs and preserving the industry in Canada. This proposal was not pursued by the federal government and their process is continuing without a deal with Ontario being completed.

The decrease in demand together with the new supply added in recent years, means that Ontario is well-positioned to examine a number of options for negotiating new nuclear production at the right time and at a cost-effective price. *(Their emphasis.)*

Laurence Named to Science and Engineering Hall of Fame

George Craig Laurence, former president of the Atomic Energy Control Board, was inducted posthumously into the Canadian Science and Engineering Hall of Fame at a ceremony held at the Museum of Science and Technology in Ottawa, October 21, 2010.

Born in Charlottetown, Prince Edward Island in 1905, Laurence's career spanned over 40 years and his work on the ZEEP, NRX and NRU research reactors helped establish Canada as a world leader in nuclear science and technology. As a student at the famous Cavendish Laboratory at Cambridge University from 1927 - 1930, Laurence studied under Ernest Rutherford (Lord Rutherford of Nelson), and along side of Sir James Chadwick and Sir John Cockcroft before returning to Canada in 1930 to work at the National Research Council (NRC). There he headed the laboratory for the standardization of measurements of X-rays and gamma rays and the development of medical and industrial uses of radiology.

Between 1940 and 1942, Laurence, with the assistance of Bernard Sargent built, largely in their own time, a graphite-uranium sub-critical nuclear assembly. That was the first induction of fission by neutrons in an atomic pile. In 1943 he joined the Montreal Laboratory as the senior Canadian. That group developed the theory and the basic design of NRX.

Laurence spent some time with the embryonic United Nations in Washington participating in the unsuccessful attempt to create a world order for the control of atomic energy. He re-joined the Montreal Laboratory group at the Chalk River Nuclear Laboratories where they had moved. Appointed Director of the Applied Physics Division he directed groups developing the instrumentation for ZEEP, the first self-sustaining reactor outside the United States, and the NRX reactor, then the most advanced reactor in the world.

The severe accident at NRX in 1952 marked a turning point for Laurence and nuclear safety become his passion. Over the next number of years he wrote many papers on the safety objective of nuclear reactors and means of achieving them that became the basis for a distinctive Canadian approach to reactor safety.

In 1956 he was appointed Chairman of the Reactor Safety Advisory Committee that had been created by the Atomic Energy Control Board to oversee the safety of reactors outside of Chalk River. Under Laurence's leadership, that Committee established many of the safety features of existing CANDU such as separate operating and shutdown systems, two independent shutdown systems and approved the vacuum containment system used at Pickering Bruce and Darlington. In 1961 he was appointed the Board's first full-time President continuing in that role until his retirement in 1970. During all that time, Dr. Laurence would spearhead regulatory standards that have proven fundamental to the exceptional safety record of Canada's nuclear power plants.

Following his retirement he continued to write and give talks on the safety of nuclear reactors until his death in 1987.

ZED-2 Reactor Given ANS Nuclear Historic Landmark Award

The American Nuclear Society has granted the ZED-2 reactor at the Chalk River Laboratories of Atomic Energy of Canada Limited its Nuclear Historic Landmark Award.

A plaque commemorating this award was presented by Joe Colvin, president of the ANS during the *Technical Meeting on Low Power Critical Facilities and Small Reactors* in Ottawa, Ontario on November 2, 2010 to Michael Zeller representing AECL.

The award identifies and memorializes sites or facilities where outstanding physical accomplishments took place that were instrumental in the advancement and implementation of nuclear technology and in the peaceful use of nuclear energy. The designation is symbolized by an inscribed bronzed plaque, which will be displayed at the ZED-2 facility at AECL's Chalk River Laboratories.

Note: It was Blair Bromley, a physicist at AECL – CRL and an active member of the CNS Council and of the ANS, who took the initiative to make the submission to the ANS Honours and Awards Committee which resulted in this award.

Joe Colvin, President of the American Nuclear Society (R) presents a plaque to Michael Zeller of Atomic Energy of Canada Limited enshrining the ZED-2 reactor as a Nuclear Historic Landmark, in Ottawa, November 2, 2010,

CAMECO Signs Deal with Chinese Nuclear Operator

In late November 2010, Cameco announced that it had signed an agreement with China Guangdong Nuclear Power Holding Co., Ltd. (CGNPC) to supply 29 million pounds of uranium concentrate under a long-term agreement through 2025.

CGNPC, China's largest clean-energy enterprise, operates three nuclear power stations and has the largest number of nuclear power plants under construction in the world. CGNPC has about 17,000 megawatts (MW) of nuclear capacity under construction and expects to have over 50,000 MW on line by 2020.

China Guangdong Nuclear Power has 14 nuclear power units currently under construction and is commencing preliminary work on another nine units.

Reports from China indicate the country plans to increase its nuclear capacity from the current 11 gigawatts (GW) to at least 80 GW by 2020. A further increase to 120-160 GW or more is planned by 2030.

The agreement follows a framework agreement with CGNPC signed in June 2010. The long-term supply agreement with CGNPC is subject to Chinese government approval.

Wolsong 1 Fuel Channels Replaced

On December 1, 2010, Atomic Energy of Canada Limited announced the successful completion in Wolsong, South Korea, of the removal and replacement of calandria tubes, pressure tubes and end fittings in a CANDU 6® nuclear reactor.

This is the first time a CANDU 6 reactor has had all of the fuel channels removed and replaced.

AECL began work on the South Korean reactor in June 2009 to replace all 380 calandria tubes of Unit 1 of the Wolsong nuclear power plant. Each calandria tube is approximately six metres long by 13 centimetres in diameter. Made of zirconium-alloy, the tubes house the reactor's 380 fuel channels. The fuel channels connect to end fittings on each fuel channel assembly to circulate heavy water coolant between the reactor and steam generators.

The next stage of work at Wolsong is to remove the multi-tonne tooling systems and the work platforms supporting them before feeder installation begins. As for the fuel channel work, this will be managed jointly by AECL and the client, Korea Hydro & Nuclear Power Company Ltd. (KHNP). The reactor is now on track to return to service for Korea's summer peak demand next year.

View of the Wolsong site

Proposals for Accelerator Isotope Production

In May 2009, shortly after the NRU shutdown, the then Minister of Natural Resources, Lisa Raitt, issued a call for expressions of interest for alternate methods of producing Mo 99 and the following month she established an "Expert Panel" to review the submissions.

In December the Expert Panel submitted its report (to a new Minister, Christian Paradis). That report listed a replacement of NRU as it s first choice but also recommended study of methods of producing medical isotopes other than reactors.

On March 31, 2010, Paradis released the government's response to the report of the Expert Panel which said:

- (1) NRU would not operate beyond 2016
- (2) the government is looking for other ways of producing Tc 99m, in particular cyclotrons and linear accelerators and will invest $35 million for research, development and demonstration
- (3) the MAPLE program will not be restarted

Several Canadian groups involved with accelerators have responded to the offer in (2).

Two groups are pursuing direct production of the Technetium 99m which is the isotope actually used for medical diagnosis. Because Tc 99m has a very short half-life of 6 hours this means the production source must be very close to the hospital where the diagnoses are being conducted.

In Vancouver, the group at TRIUMF has collaborated with the BC Cancer Agency, Applied Physics Solutions, the Centre for Probe Development and commercialization, the Lawson Health Research Institute and the University of British Columbia to prepare a proposal for direct production of the Technetium 99m.

In Alberta, a group at the University of Alberta in association with the Cross Cancer Centre has demonstrated production of Tc 99m with their cyclotron and is pursuing the various related matters of ensuring the purity of the production and the logistics involved.

In Ottawa, a team at the National Research Council in collaboration with the Ottawa Hospital and other partners has demonstrated that they can produce Molybdenum 99, the current product of NRU and the various other isotope producing reactors around the world, by their linear accelerator. The group has already developed a business plan which shows that two similar linear accelerators could meet the full Canadian demand.

Bruce Completes Calandria Tube Installation

On November 10, 2010, Bruce Power announced the successful completion of the installation of new calandria tubes in the Unit 1 reactor of the Bruce A plant. With the same task being accomplished in Unit 2 just three months earlier this completes the challenging task that has been the subject of much commentary and criticism.

Duncan Hawthorne, Bruce Power's President and CEO, commented, "Our team has worked with great professionalism and focus to complete their work programs in a manner that reflects well on their skill and is a testament to the quality of our Canadian workforce."

Final seal tests concluded the work sequence, which saw 480 new tubes installed horizontally in the reactor vessel. Approximately six metres long by 13 centimetres in diameter, the zirconium-alloy tubes are used to house the reactor's 480 fuel channels.

The first calandria tube was installed in the Unit 1 reactor during a trial run in December 2009 after Atomic Energy of Canada Limited (AECL) crews spent more than two years with remote-controlled tools removing the original core components and refurbishing what remained. The final tube was secured on Oct. 27, 2010 and all seal tests were successfully achieved by Nov. 10, 2010.

Calandria tube installation was completed in parallel with other tasks to prepare feeder tubes, clean the reactor vessel's inside surfaces and install initial fuel channel assemblies. To date, crews have installed 38 of 480 new fuel channels in the Unit 1 reactor.

Individual feeder tubes connect to end fittings on each fuel channel assembly to circulate heavy water coolant between the reactor and steam generators. The lower segment of each feeder tube was removed earlier in the project to be replaced after new fuel channels are installed.

The four 750 megawatt units at Bruce A were laid up in the mid-1990s by former operator Ontario Hydro. Units 3 and 4 were restarted by Bruce Power earlier this decade; Unit 2 is expected to synchronize with Ontario's electricity grid in late 2011 with Unit 1 following in 2012.

Commons Committee Issues Report on NRU and Isotopes

In late November, the Standing Committee on Natural Resources of the House of Commons released its report: *The National Research Universal Reactor Shutdown and the Future of Medical Isotope Productions and Research in Canada.*

This 64 page report is based on the series of hearings conducted by the Committee during 2009 at which a long list of knowledgeable witnesses appeared.

The report provides some interesting information and contains a number of conclusions and recommendations. In the category of information it presents the following costs of operating NRU as provided by Atomic Energy of Canada Limited.

Following are some of the Committee's recommendations:

Recommendation 3: Considering the important role that Canada plays in the production of medical isotopes, the Committee recommends that the Government of Canada continue to support Canadian involvement in isotope production, especially through the Non-reactor-based Isotope Supply Contribution Program.

Recommendation 4: In the meantime, the Committee recommends that the federal government conduct a cost-benefit analysis of isotope production, and evaluate future production levels of isotopes.

Recommendation 8: In light of this evidence, the Committee recommends that, when necessary, the Government of Canada encourage the use of alternative medical isotopes for diagnostics.

Recommendation 10: The Committee recommends that the Government of Canada study the feasibility of a new multi-purpose research reactor in order to accurately estimate construction and operating costs as well as potential sources of income and report the results to Parliament.

Table 1: NRU Operating: and Capital Expenditures

Actual (millions $)

	2000 - 01	2004 - 05	2008 - 09
Operating Expenditures			
Labour Costs (operation and monitoring, fuelling, maintenance and upgrading, troubleshooting and repair, etc.)	15.8	20.1	32.3
Other Expenditures (reactor fuel, materials and equipment, waste management, etc.)	8.8	11.2	25.6
Total Operating Expenditures	24.6	31.3	57.8
Total Capital Expenditures (experimental system within the reactor planned for ACR fuet qualification)			7.1
Total Expenditures	24.6	31.3	64.9

Source: Document presented to the Committee on October 20, 2009 by Serge Dupont, Special Advisor to the Minister of Natural Resources on Nuclear Energy Policy.

Recommendation 12: The Committee recommends that the federal government learn from the failure of the MAPLE reactors and the impact of the NRU shutdown on medical isotope supplies in Canada, and seek to diversify and secure the supply sources of medical isotopes in the medium and long term by funding several projects out of the $35 million envelope announced in the last federal budget.

Recommendation 13: Furthermore, the Committee recommends that the Government of Canada examine fully all the alternative production proposals, and continue to support the research and development of new technologies.

Recommendation 14: In particular, the Committee recommends that the Government of Canada continue to fund research in accelerator technology, both linear accelerators and cyclotrons.

The report contains considerable background information. Anyone interested in obtaining a perspective on what had been termed the "isotope crisis" should read it.

It is available on the HOC website but is also posted on the CNSC website: www.nuclearsafety.gc.ca

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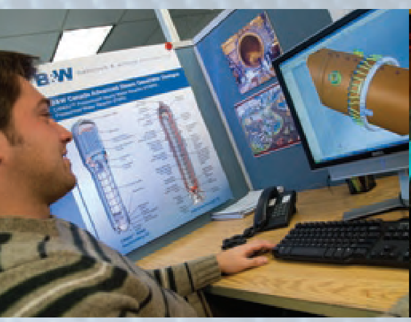


CNS news

CNS Member Honored by Province

On Nov. 23, 2010, **Mohinder Grover**, a Senior Quality Engineer at Atomic Energy of Canada Limited, Sheridan Park and an active member of the Canadian Nuclear Society, was awarded the **Ontario Medal for Good Citizenship** during a ceremony at Queen's Park. This award recognizes people who, through exceptional long-term efforts, have made outstanding contributions to the well-being of their communities.

Minister of Citizenship and Immigration, Eric Hoskins, highlighted Mohinder's work in the fields of reliability and quality engineering; his efforts in promoting employment equity and diversity activities in the workplace; and his support of several charitable causes. Then Lieutenant Governor, David Onley, presented him with the medal commemorating the award. A special dinner followed the awards ceremony.

Mohinder Grover came to Canada from India as a graduate student in 1970 with seven dollars in his pocket. In just a few years, after completing his Doctorate degree, he became a professional engineer, a recognized authority in the field of reliability engineering and quality engineering in Ontario, and a promoter for employment equity and diversity activities within Ontario Hydro, Ontario Power Generation and Atomic Energy of Canada Limited.

Mohinder has helped others to achieve their goals and dreams. In addition to supporting several charitable causes, he has been committed to using his experience to guide international engineering graduates to obtain professional engineer licensure in Ontario, and to mentoring immigrants and refugees to access in the workplace, and in the wider community.

Mohinder has also served on committees representing the Sikh community, and actively promotes respect and understanding among different faiths.

At Sheridan Park, Mohinder is well-known for taking part in the Terry Fox Run each year (he hasn't missed a run in 26 years); raising funds for our Salvation Army food and toy drive; leading *Diwali* celebrations together with Employees with Roots in India; and acting as an emergency steward and first aider.

Mohinder Grover is shown (L) with Lieuteneant Governo David Onley (seated) and Ontario Minister of Citizenship and Immigration, Eric Hoskins, after being awarded a Medal of Good Citizenship at a ceremony at Queen's Park, November 23, 2010.

Outside of AECL, some of his current volunteer work includes helping foreign-trained candidates obtain their licenses through Professional Engineers Ontario; mentoring new immigrants and refugees through Skills for Change; acting as a founding member of Gursikh Sabha Canada, a Sikh place of worship; as well as supporting the United Way and Habitat for Humanity.

Former AECL President Receives International Award

At a special ceremony on October 30, 2010, the closing day of the 2010 Pacific Basin Nuclear Conference held in Cancun, Mexico, **Dr. Stanley Hatcher** was presented with the Global Award by the president of the International Nuclear Societies Council (INSC).

The qualification for the INSC Global Award is:

An individual or group who shall have performed international professional efforts in developing nuclear technology in a sustainable manner for the welfare of society.

It is presented periodically by the INSC, an organization that has membership of most of the nuclear societies around the world. The previous recipient, in 2008, was Dr. Bertrand Barré of France.

Hatcher was president of Atomic Energy of Canada Limited from 1989 to1992. He joined AECL in 1958 immediately after receiving a Ph.D. in chemical engineering from the University of Toronto. Over the following years he became head of the Chemical Technology Branch; Director, Applied Science Division at the Whiteshell Laboratory; Vice-President of Whiteshell; President of AECL Research Company and then CEO of the company. He was presented the Ian McRae Award by the Canadian Nuclear Association in 1991.

Internationally he was president of the Pacific Nuclear Council which represents nuclear societies and associations of countries around the Pacific Rim from 1994 to 1996, and President of the American Nuclear Society 1997 – 1998. Also active with the INSC he oversaw the preparation of its report *Vision for the next 50 years of Nuclear Energy* published in 1996.

After leaving AECL, Hatcher created Strategists Consultancy Ltd. and continues to advise companies and countries around the world. He is a charter member of the Canadian Nuclear Society.

The citation for the award reads:

For his exceptional leadership in the promotion of nuclear technology information sharing with other countries, particularly of CANDU-type reactors, through technical exchanges, and technology transfer, and in setting up international programs of nuclear co-operation with members and institutions of different countries of the Pacific Rim and Europe.

Team Award for NRU Finally Presented

At the Honours and Awards ceremony during the CNS Annual Conference in 2009 one award was not actually presented.

The problem was that the award, the J. S. Hewitt Team Achievement Award, was for all of those who had kept the NRU reactor at the Chalk River Laboratories of Atomic Energy of Canada Limited running for the past 53 years. However, everyone associated with NRU was deeply involved in the exceedingly difficult repair of the leaks in the reactor vessel that had just been discovered and no one was available to accept the award.

With the repair successfully completed in August 2010 the next challenge was to determine an appropriate occasion to present the award.

That came when AECL held an appreciation evening for those involved in the NRU repair in early October in Petawawa…

Frank Doyle, 1st Vice President of the Canadian Nuclear Society attended the function and presented the award to Bill Shorter who accepted it on behalf of all of the NRU current and past team.

The award was created in honour of J.S. Hewitt, a long-time professor of nuclear engineering at the University of Toronto, a founding member of the CNS in 1979 and the third CNS president, from 1983 to 1984. The award recognizes exemplary achievements in the nuclear field by a team nominated by its peers.

The citation reads:

To the operations staff, past and present, of the National Research Universal (NRU) reactor for dedicated and skilled teamwork that has ensured safe operation and invaluable service to industry, science and medicine for over a half a century.

CNS Issues Report on Need for New Research Reactor

The Canadian Nuclear Society has issued a new report, *Maintaining Excellence: Planning a New Multi-Purpose Research Reactor for Canada* which summarizes the urgent need for a new facility to replace the ageing NRU reactor at the Chalk River Laboratories of Atomic Energy of Canada Limited.

It summarizes the history of the NRX and NRU reactor over the years in providing the scientific basis for Canada's nuclear power program, producing isotopes for medical purposes, and for the internationally renowned research on neutron scattering. The two reactors enabled research that was respected world wide.

The report was sent to the Prime Minister, Cabinet Ministers, Members of Parliament, Senators and selected senior government officials. It points out that a new multi-purpose research reactor would meet the four principles of the government's principles for a national science and technology strategy: promoting world-class excellence; encouraging partnerships; focusing on priorities and enhancing accountability.

The report was also mailed to all members in November 2010. If, as a member, you did not receive your copy contact the CNS office. Other readers, if you wish a copy you are invited to request one. *CNS e-mail: cns-snc@aibn.on.ca.*

Graduate Scholarship — Bourse au doctorat

Dr. Glenn Harvel of UOIT, who led the graduate scholarship selection process for 2010, reports that there were 13 submissions, coming from École Polytechnique de Montréal, University of Ottawa, RMC, McMaster University, and University of Western Ontario. The scholarship was awarded to Ms. Geneviève Harrisson of École Polytechnique de Montréal, for the thesis entitled «Optimisation des caractéristiques de sûreté du réacteur nucléaire refroidi à l'eau surcritique à l'aide des codes DRAGON et DONJON». The research will be performed under the supervision of Dr. Guy Marleau.

Le docteur Glenn Harvel, de UOIT, qui a dirigé le processus de 2010 de sélection de la bourse au doctorat, indique qu'il y a eu 13 demandes, venant de l'École Polytechnique de Montréal, de l'Université d'Ottawa, du Collège Militaire Royal, de l'Université McMaster, et de l'Université de Western Ontario. La bourse a été attribuée à Mlle. Geneviève Harrisson de l'École Polytechnique de Montréal, pour sa thèse intitulée «Optimisation des caractéristiques de sûreté du réacteur nucléaire refroidi à l'eau surcritique à l'aide des codes DRAGON et DONJON». La recherche sera effectuée sous la responsabilité du Dr. Guy Marleau.

Membership Note

It is time to renew your CNS membership for 2011. You probably already know that we have a new CNS-members-only page where you can update your profile if you need to, and where you can very easily and quickly renew your membership. You should in fact have already received an explanatory e-mail with a link for you to access your profile and renew your membership if it expires this coming December. If you have not received such an e-mail, it may be because your e-mail address has changed; if that is the case, please let us know your new address.

If we do not have an e-mail address for you, please send it to us. If you definitely have no access to a computer, please let the CNS office know (416-663-3252), to arrange a different way of renewing.

If you were on "automatic" renewal, please note that we are discontinuing this service, in view of the very easy way now available for you to renew and to keep you profile current.

Regarding renewal fees, the CNS will be maintaining the membership fees unchanged for 2011, even with the advent in Ontario of the HST. And earlybird renewal fees are available right now, until December 31, so I encourage you to take advantage of the discount!

And please remember to keep your profile current when there are changes in your information. You can access your account at any time by logging in to https://cns-snc.ca/accounts/login (or via the Membership page of the CNS website, www.cns-snc.ca).

Ben Rouben
Chair, Membership Committee

Note d'adhésion

Il est temps de renouveler votre adhésion à la SNC pour 2011. Vous savez sans doute déjà qu'il y a une page internet pour membres de la SNC seulement, où vous pouvez mettre à jour vos données personnelles s'il le faut, et où vous pouvez renouveler votre adhésion très facilement et rapidement. En fait, vous devez avoir déjà reçu un courriel explicatif avec un lien à votre compte, ou vous pouvez aussi renouveler. Si vous n'avez pas reçu ce courriel, c'est peut-être à cause d'un changement dans votre adresse électronique ? Dans ce cas, veuillez nous communiquer votre nouvelle adresse.

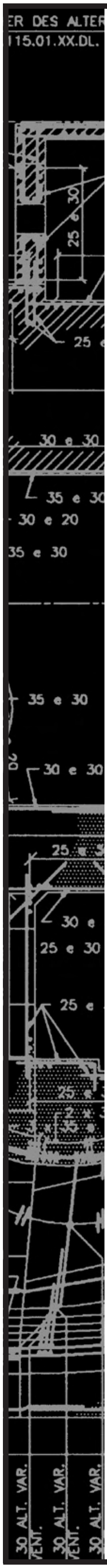
Si nous n'avons pas d'adresse électronique pour vous, veuillez nous l'envoyer. Si vous n'avez absolument pas d'accès à un ordinateur, veuillez communiquer ce fait au bureau de la SNC (416-977-7620), pour un autre moyen d'effectuer votre renouvellement.

Si vous vous étiez inscrit au renouvellement « automatique », veuillez noter que nous mettons fin à ce service, vu que vous avez dès lors un moyen très facile et de renouveler et de mettre vos données à jour.

Á propos des frais de renouvellement, la SNC gardera les frais d'adhésion pour 2011 au même niveau, malgré l'arrivée de la TVH en Ontario. Et il y a un escompte pour les renouvellements jusqu'au 31 décembre, et je vous encourage donc d'en profiter !

Et veuillez bien vous rappeler de mettre vos données à jour chaque fois qu'il y a un changement. Vous pouvez accéder à votre compte en tout temps en visitant https://cns-snc.ca/fr/accounts/login ou bien à partir de la page des adhésions au site de la SNC (www.cns-snc.ca).

Ben Rouben
président du comité d'adhésion



Département de génie physique

L'École Polytechnique de Montréal, l'un des plus importants établissements d'enseignement et de recherche en génie au Canada, comptant plus de 6 500 étudiants et plus de 1 000 personnes à son emploi, est à la recherche de candidats pour combler un poste de professeur menant à la permanence dans le domaine de l'ingénierie des réacteurs nucléaires au Département de génie physique.

Professeur en génie nucléaire

Les candidats doivent posséder une solide expérience dans le domaine de la thermique des réacteurs nucléaires et des expertises dans l'un ou plusieurs des sujets suivants : l'étude du transfert de chaleur appliquée aux réacteurs de puissance incluant les fluides supercritiques, les écoulements soniques, l'ébullition en convection forcée et le flux de chaleur critique; la capacité de monter et d'analyser des expériences bien ciblées ainsi que de développer des modèles physiques et numériques en thermohydraulique; le couplage entre les logiciels de calcul en neutronique et en thermique des réacteurs.

Le candidat recherché doit posséder un doctorat (Ph. D.) en génie physique, en génie nucléaire, en physique ou dans une discipline pertinente. Il doit être membre de l'Ordre des ingénieurs du Québec ou prendre les mesures nécessaires afin de le devenir au cours de son premier contrat. Le candidat retenu devra enseigner en français au premier cycle et aux cycles supérieurs et s'impliquer dans la direction d'étudiants à la maîtrise et au doctorat. Il devra également développer un programme de recherche de haut niveau. Le candidat retenu s'intégrera à l'équipe de professeurs du département ayant une expertise reconnue en physique de la matière condensée, en photonique et en génie nucléaire. Les membres du département sont impliqués dans plusieurs réseaux de recherche bien établis (voir notre site Web pour plus de détails : **www.polymtl.ca/phys**).

Mise en candidature

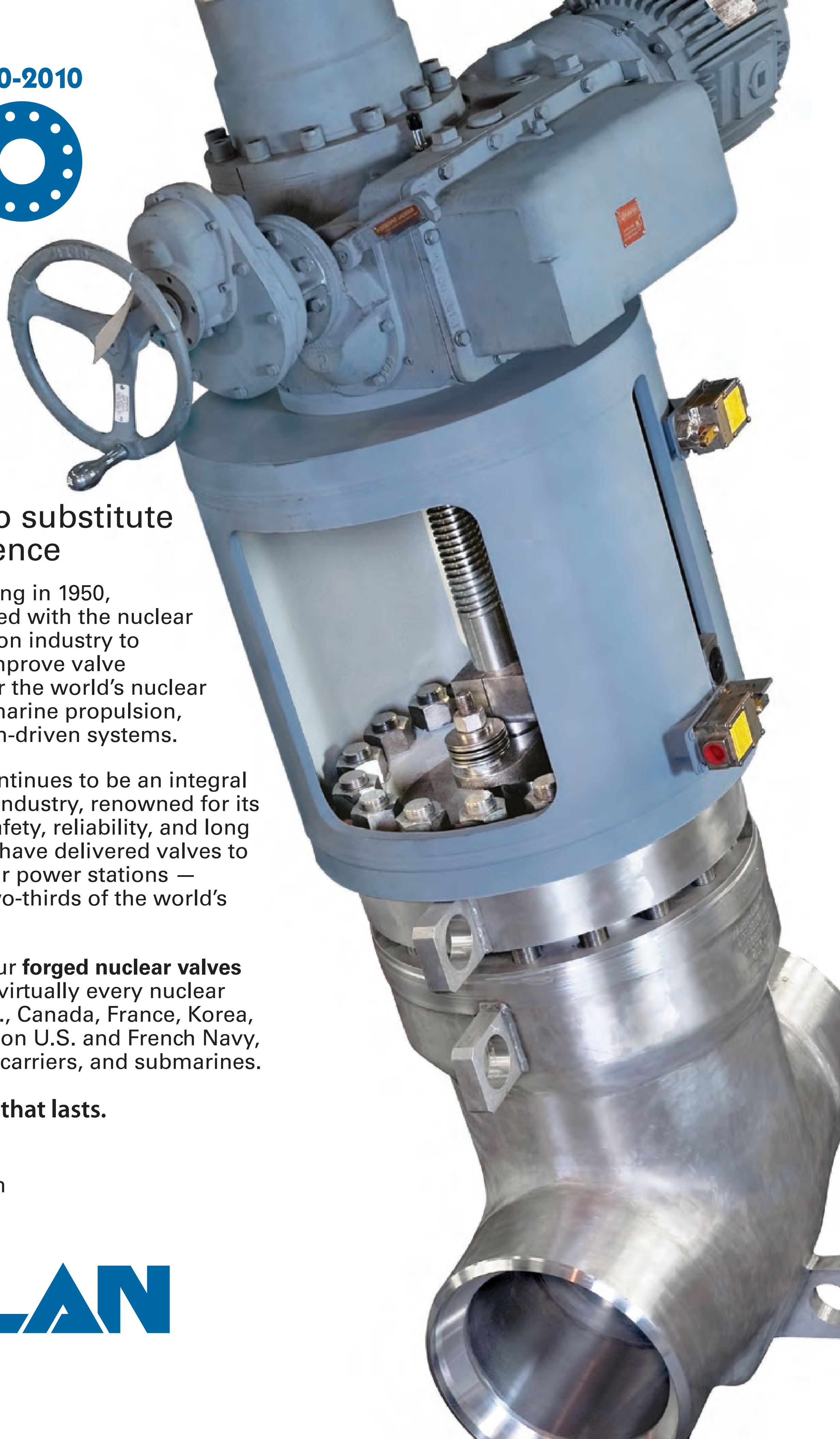
Les candidats sont invités à soumettre leur curriculum vitæ, un énoncé de leurs objectifs en enseignement et en recherche, des évaluations d'enseignement, une attestation de leurs diplômes, les noms de trois répondants, quelques exemples de travaux reliés au poste ainsi que des tirés à part de contributions récentes. Le tout doit être envoyé le plus tôt possible à l'attention de : **Patrick Desjardins, Professeur titulaire et directeur, Département de génie physique, École Polytechnique de Montréal, C. P. 6079, Succursale Centre-ville, Montréal (Québec) H3C 3A7 Canada**

Pour information ou pour annoncer votre candidature : **postes@phys.polymtl.ca**
L'examen des candidatures débutera le 21 janvier 2011 et se poursuivra tant que le poste n'aura pas été pourvu. Tous les candidats qualifiés sont invités à poser leur candidature; néanmoins, cette offre s'adresse de préférence aux citoyens canadiens et aux résidents permanents. Pour faciliter la lecture du texte, seul le genre masculin a été utilisé.

ÉCOLE
POLYTECHNIQUE
MONTRÉAL

Seuls les candidats retenus recevront une réponse écrite. Conformément aux exigences prescrites en matière d'immigration au Canada, ces offres s'adressent de préférence aux citoyens canadiens et aux résidents permanents.

L'École Polytechnique souscrit à un programme d'accès à l'égalité en emploi et à un programme d'équité en emploi pour les femmes, les membres des minorités visibles et ethniques, les Autochtones et les personnes handicapées.



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Société Nucléaire Canadienne

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CNS Scholarship for PhD Graduate Research

The Canadian Nuclear Society is pleased to offer a scholarship to promote nuclear science and engineering in Canadian universities.

This scholarship is designed to support *a PhD-level full- time graduate student entering his/her second or third year of graduate research in nuclear science and engineering at a Canadian University*.

One award of $10,000 per year for a total of two years is available

The scholarship will be awarded to a PhD candidate for a specific research project related to nuclear science and engineering. There must be a faculty member supervising the research.

The award will be applied as partial payment of the student's earnings during the two-year period. Note that funding for the second year is conditional on satisfactory progress in the first year of the award.

Awards will be based on the academic standing of the student and the merit of the proposed research. An independent panel, appointed by the CNS, will review submissions and make award decisions.

Guidelines for submission

The faculty member responsible for the research must be a CNS member in good standing.

The student must be enrolled in a PhD graduate degree program at a Canadian University and be a member of the CNS.

The research duration must be at least two years remaining.

Applications should be prepared by the students and include:

- Student CV and grades (undergraduate and graduate)
- Research Proposal including the thesis topic, objective and relevance to nuclear science and engineering in Canada, details of the research approach and the schedule for completing the research work, including the submission of a full-length peer-reviewed paper within 6 months of the end of the award (maximum 4 pages, in 12pt, MS Word document).
- A letter of support from the thesis supervisor stating the quality of the student and that the approach is sound.

Submission procedure

The application must be sent by e-mail to:

ecc@cns-snc.ca

Deadlines

- Submission deadline: April 15, 2011
- Notice of Awards: May 10, 2011 (all applicants to be informed). The official award presentation will be made during the student awards ceremony at the CNS annual conference in Niagara Falls in 2011 June.
- 1st Installment: September 1, 2011
- 2nd Installment: September 1, 2012

Deliverables

A paper is to be presented at the 2012 CNS/CNA Student Conference in Saskatoon.

A full-length peer-reviewed conference paper or journal paper covering the work is to be published within one year following the end of the award's period.

Questions should be addressed to:
e-mail: cns-snc@on.aibn.com

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Bourse de recherche au doctorat de la SNC

La Société nucléaire canadienne est heureuse d'offrir une bourse afin de promouvoir la recherche en science et génie nucléaire dans les universités canadiennes.

Cette bourse doit servir à supporter financièrement un(e) *étudiant(e) au doctorat de deuxième ou troisième année à inscrit à temps plein dans une université canadienne et travaillant sur un sujet relié à la science ou au génie nucléaire.*

Une bourse de 10,000$ par année sera accordée pour une période totale de 2 ans

Cette bourse sera attribuée à un(e) candidat(e) au doctorat pour un travail de recherche relié à la science ou au génie nucléaire. Un professeur d'une université canadienne reconnue doit être responsable du projet.

La bourse servira à compléter l'aide financière qui sera versée à l'étudiant(e) pour la période visée. Le renouvellement de la bourse pour une deuxième année est conditionnel à un avancement adéquat de travail au cours de la première année.

Les critères pour l'attribution de la bourse sont la qualité du dossier académique de l'étudiant et du projet proposé. Les candidatures seront étudiées par un jury indépendant, nommé par la SNC, qui attribuera les bourses.

Critères d'éligibilité

L'étudiant(e) doit être inscrit(e) à un programme de doctorat dans une université canadienne et membre de la SNC. Le professeur responsable du projet doit être un membre de la SNC.

L'échéancier du projet de recherche doit couvrir une période minimale de deux ans.

La demande de bourse doit contenir :

- Un CV et les relevés de notes de l'étudiant(e)
- Une description du projet incluant une discussion de la pertinence du projet pour la science ou le génie nucléaire au Canada, une présentation de objectifs du travail et un échéancier (maximum 4 pages, 12pt, document MS Word).
- Une lettre de recommandation du directeur de thèse.

Procédure de soumission

Les dossiers doivent être transmis par courriel à :

ecc@cns-snc.ca

Dates importantes

- Date limite de soumission: 15 avril 2011
- Annonce des résultats: 10 mai 2011
  (tous les postulant(e)s seront informé(e)s). La présentation officielle de la bourse aura lieu durant le cérémonie des prix aux étudiants à la Conférence annuelle de la SNC en juin 2011 à Niagara Falls.
- Premier versement 1 sept. 2011
- Second versement 1 sept. 2012

Rapports

L'étudiant(e) doit soumettre et présenter un article à la Conférence étudiante de la SNC et de l'ANC à Saskatoon en 2012.

L'étudiant(e) devra rédiger et soumettre un article dans une revue ou une conférence avec comité de lecture au plus tard un an après la date d'échéance de la bourse.

Adressez vos questions par courriel à:
cns-snc@on.aibn.com

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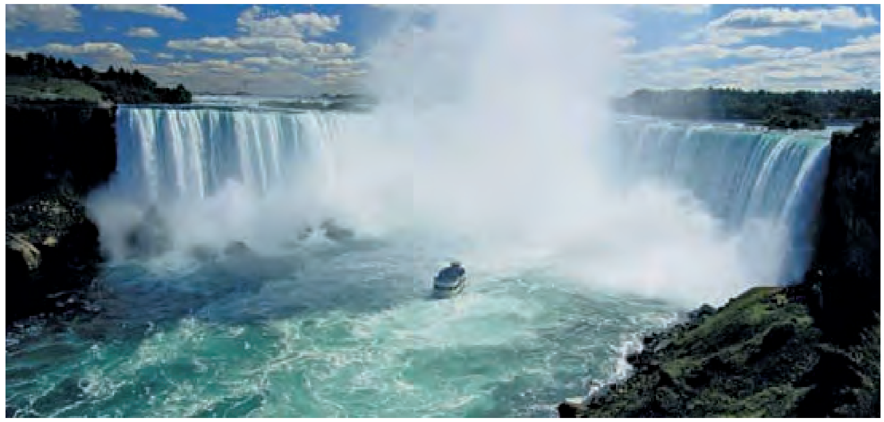

32^{nd} Annual CNS Conference & 35^{th} CNS/CNA Student Conference
Niagara Falls, Ontario, Canada
2011 June 5-8

Conference webpage: www.cns-snc.ca/events/conf2011

The 32^{nd} Annual Conference of the Canadian Nuclear Society and the 35^{th} Annual CNS/CNA Student Conference will be held in Niagara Falls, Ontario, Canada, 2011 June 5-8 at the Sheraton on the Falls Hotel, Niagara Falls, ON.

The central objective of this conference is to exchange views on how nuclear science and technology can best serve the needs of humanity, now and in the future. Plenary sessions will address Canadian and Global Energy and Environmental Developments, Communicating the Nuclear Message, Isotopes and Nuclear Medicine, Alternative Energy Technologies, and New Nuclear Technologies. Papers are being solicited on technical developments in all subjects related to nuclear science and technology and their great potential for service to the world community. There will also be an embedded Student Conference featuring topical poster displays.

Important Dates:

2011 January 31	**Deadline for submission of full papers**
2011 March 31	**Deadline for submission of revised full papers**
2011 April 15	**Deadline for early-bird registration**

This call for papers is to solicit papers on all aspects of nuclear science and technology. The full Call for Papers, including suggested Technical Topics, Guidelines for Papers and the paper template, is on the conference website.

Paper Submission

Please note that ONLY FULL PAPERS are to be submitted. Submissions should be made electronically, preferably in MS Word format, through the Annual Conference and Student Conference submission websites respectively:

https://www.softconf.com/b/CNS2011Technical
https://www.softconf.com/b/CNS2011Students

(To help with planning, please log in and input the title and primary author of your paper even before making the full submission.)

2011

Feb. 23-25 — **CAN Nuclear Industry Conference and Trade Show 2011**
Ottawa, Ontario
website: www.cna.ca

March 13-16 — **5th International Symposium on Supercritical Water-Cooled Reactors (ISSCWR-5)**
Vancouver, British Columbia
Call for papers
website: www.cns-snc.ca/events/isscwr-5/

Apr. 10-14 — **ANS International High-Level Radioactive Waste Management Conference**
Albuquerque, New Mexico
website: www.ans.org/meetings/ihlrwm

June 5-8 — **32nd CNS Annual Conference and 35th CNS/CNA Student Conference**
Niagara Falls, Ontario
Call for papers
website: www.cns-snc.ca/events/conf2011

June 26-30 — **ANS Annual Meeting**
Hollywood, Florida
website: www.ans.org

Sept. 11-14 — **Waste Management, Decommissioning & Environmental Restoration for Canada's Nuclear Activities**
Toronto, Ontario
Call for papers
website: www.cns-snc.ca/eventswaste-management-decommissioning-and-environment

Sept. 25-29 — **14th International Topical Meeting on Nuclear Reactor Thermalhydraulics (NURETH-14),**
Toronto, ON
Call for papers
website: www.cns-snc.ca/events/nureth-14/

Oct. 2-5 — **International Conference on Future of Heavy Water Reactors**
Vancouver, BC
email: ISSCWR5@cns-snc.aibn.ca
website: www.cns-snc.ca

Dec. 4-6 — **9th International Conference on CANDU Maintenance**
Toronto, Ontario
website: www.cns-snc.ca

Waste Management, Decommissioning and Environmental Restoration for Canada's Nuclear Activitities

Current Practices and Future Needs

The Canadian Nuclear Society is pleased to announce a conference on **Waste Management, Decommissioning and Environmental Restoration for Canada's Nuclear Activities,** to be held September 11-14, 2011 at the Marriott Toronto Downtown Eaton Centre, in downtown Toronto. An equipment and services exhibition is planned in conjunction with the conference.

Second Announcement and Call for Paper Summaries

The conference is intended to provide a forum for discussion of the status and proposed future directions of technical, regulatory, environmental, social, and economic aspects of radioactive waste management, nuclear facility decommissioning, and environmental restoration activities for Canadian nuclear facilities. Although the conference will focus on activities pertaining to Canada's nuclear industry, many of the technical issues involved have a broader relevance, therefore papers on the topic of the conference from outside the nuclear industry, and from other countries, will be welcome.

The conference is organized into plenary sessions and concurrent technical tracks and papers are being solicited for the Technical Sessions.

Topics to be addressed during the conference will include the following:

- Near-surface disposal of very low level waste
- Low and intermediate level waste management issues, with an emphasis on geological disposal and operational issues faced by waste-producers such as waste segregation, characterization, verification; treatment and processing; waste minimization, and waste inventories
- Uranium mining, milling and conversion wastes
- Transportation
- Used nuclear fuel, with an emphasis on geological disposal, but including storage practices
- Decommissioning and environmental remediation, including that of old waste management facilities
- Licensing and regulatory considerations, including standards and clearance criteria
- Social issues, including siting of facilities, and decision-making criteria and processes

Deadlines

- Submission of Paper Summaries: October 4, 2010
- Author notification of acceptance: November 12, 2010
- Submission of full papers: May 13, 2011
- Comments to authors on papers: August 15, 2011
- Submission of final full papers: September 11, 2011

Guidelines for Submission of Paper Summaries

Paper Summaries should be approximately 750 to 1200 words in length (tables and figures counted as 150 words each).

They should include:

- an introductory statement indicating the purpose of the work
- a description of the work performed
- the results achieved

Summaries are to be submitted no later than October 4, 2010 by e-mail to Mark Chapman: **CNSP2011@aecl.ca**

For more details see the conference website http://www.cns-snc.ca/events/waste-management-decommissioning-and-environmental/

Post Conference Technical Tours

Technical tours are being planned to three Canadian nuclear facilities: the Low-Level Radioactive Waste Management Office activities at Port Hope, the Darlington Used Fuel Dry Storage Facility, and the OPG Western Waste Management Facility at the Bruce site.

Questions regarding papers and the Technical Program should be addressed to:

Mark Chapman
E-mail: CNSP2011@aecl.ca

General questions regarding the Conference should be addressed to:

Elizabeth Muckle-Jeffs
Conference Administrator
The Professional Edge
Tel. North America toll-free: 1-800-868-8776
Tel. International: 1-613-732-7068
Fax: 613-732-3386
Email: Elizabeth@TheProfessionalEdge.com

Questions about Conference registration should be addressed to:

CNS Office
Tel.: 416-977-7620
E-mail: cns-snc@on.aibn.com

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The conference is being organized by the Canadian Nuclear Society in cooperation with the International Atomic Energy Agency, and is co-sponsored by the American Nuclear Society, the Argentina Nuclear Technology Association, the Atomic Energy Society of Japan, the Chinese Nuclear Society, the Indian Nuclear Society, the Korean Nuclear Society, the Nuclear Energy Agency of the OECD and the Romanian Nuclear Energy Association.

Till Fear Do Us Part

by Jeremy Whitlock

ONTARIO – Never mind recycled steam generators or radium-tainted soil; nuclear critics are now drawing attention to an even more dangerous handling of radioactive material in this province.

"To be honest, our biggest concern", says Garbled Efforts, president of the Canadian Coalition for Anti-Nuclear Irresponsibility, "is the completely unregulated daily movement of potassium-40 and carbon-14 around Ontario. We're talking about the waterways, the highways, the railways, and over our very heads on aircraft."

Efforts claims that the problem has been around for decades, and seems to fly under the radar of officials at all levels. Other critics suggest deeper issues.

"There hasn't been a decent epidemiological study," says internationally acclaimed Australian pediatrician Hellishly Callous. "The whole thing is medically corrupt from beginning to end."

The problem, says Callous, is people.

"It's a disaster. You can't clean it up." Callous explains, "As my book explains, people are toxic time bombs. Every human body has about 10,000 becquerels of carcinogenic carbon and potassium. That's 10 trillion nanobecquerels of death. Imagine 10 trillion mini-nuclear explosions every second in your body, each sending out a death sentence to your children, your loved ones."

Callous explains that human bodies are very efficient at concentrating radioactive potassium and carbon atoms out of the environment.

"And they don't go anywhere," she warns, "As I explain in my book, carbon has a half-life of about six thousand years. That's as old as fear itself! Potassium has a half-life of over a billion years. This stuff just doesn't go away."

John Bendit, Executive Director of the Silly Club of Canada, describes how concentrations of people on buses, trains and ships can lead to environmental disaster, even for very small spillages of people.

"Radioactive chemicals would take centuries to erase. An infinitely smaller volume of nuclear material would have a similar impact as a large, large oil spill. It would be impossible to decontaminate."

"The governments of Ontario and Canada," adds Garbled Efforts, "must prohibit these shipments because the transport of radioactive people through our precious waterways should not be condoned, should not be countenanced."

"And highway traffic is a risk as well. Every day, zillions and zillions of nanobecquerels are moved through Toronto on the 401. So much that even the Darlington Nuclear Station built an earthen berm between it and the freeway, to shield it from the excess radiation. That tells you something."

"As I explain in my book," Dr. Callous points out, "there is enough deadly radioactive potassium and carbon in two human bodies to require a licence from Canada's nuclear regulator for possession - were it not well hidden inside the bodies of our children and loved ones."

Callous brought her dire message to Ontario citizens recently as a guest speaker of the activist group Families Are Radiation Exposure (FARE). In her comments Callous advised Ontarians to walk away from their homes, their marriages, their schools, their cities, and head for the hills.

"Then sue the government. This government should be sued and you should get millions and millions of dollars," Callous said to cheers and applause. "That's quadrillions and quadrillions of nanodollars."

"The federal government should pay to separate everyone," insists Callous, who was shocked to see people walking next to each other as she toured one small Ontario town prior to her presentation.

Mayors in Ontario have dismissed Callous' comments as "sensationalism", but Callous urges citizens to "read, check the facts, check my data, buy my book - and make your own decision."

"And don't forget, as my book says", added Callous, "that children are most at risk."

Asked how governments and other officials could condone such a dangerous situation for radioactive citizens for so long, Garbled Efforts replied, "It's simple. They are liars. They are in the business of lying exactly like the tobacco industry."

"It's time for people to trust the real experts at that game."

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