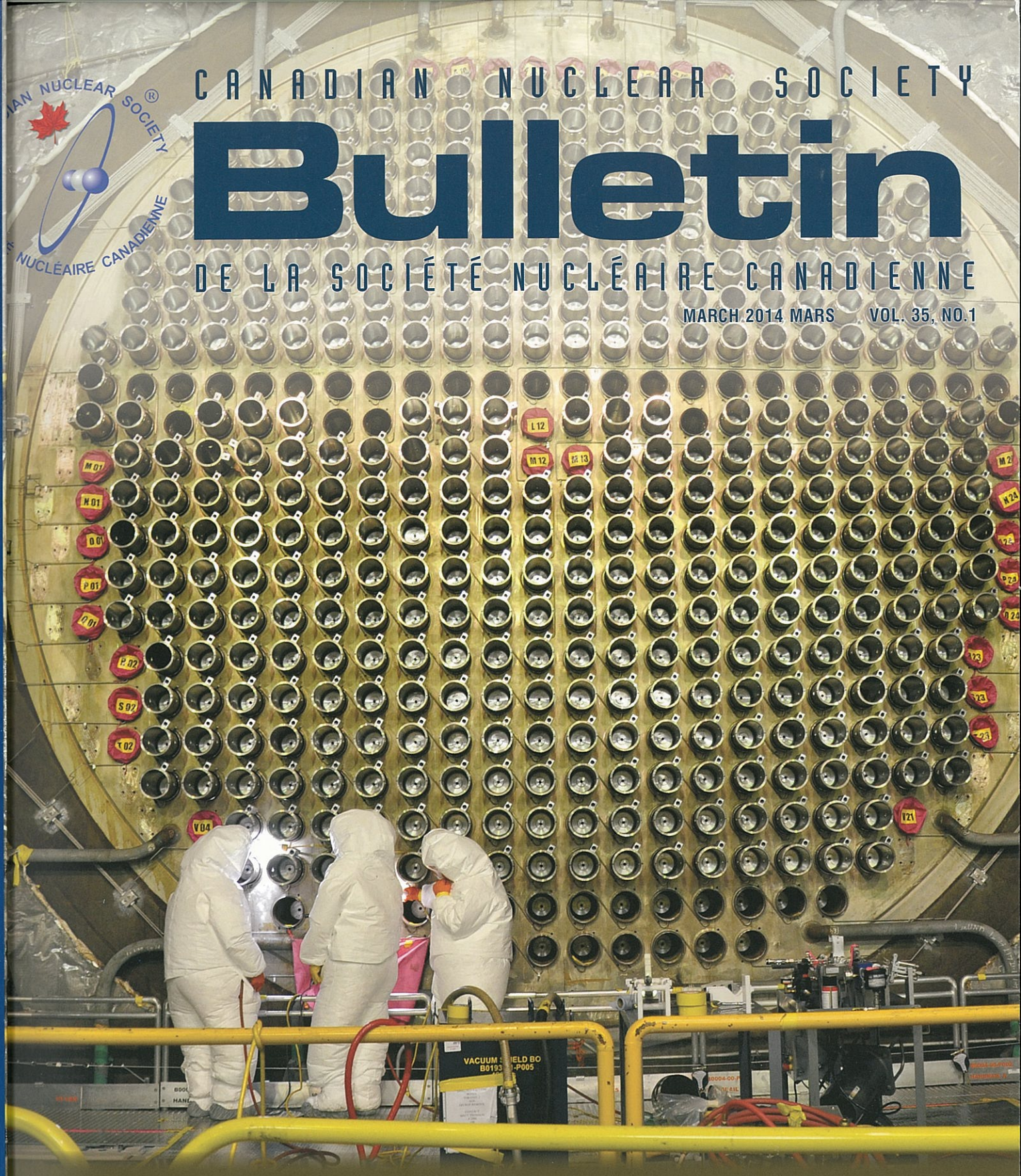
CANADIAN NUCLEAR SOCIETY

Bulletin

DE LA SOCIÉTÉ NUCLÉAIRE CANADIENNE

MARCH 2014 MARS VOL. 35, NO.1



- CNA Conference and Trade Show
- Radium and Radiation: A Personal Memoir
- International CANDU Fuels Conference Papers
- News and Endpoint



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Working with Radium



This edition of the Bulletin features a personal memoir by Don Wiles, Emeritus Professor of Chemistry at Carleton University in Ottawa. He shares some valuable insights into the workings at Port Hope, Ontario which was then Eldorado Mining and Refining Co. in the 1940s (presently CAMECO). His job, as a newly graduated chemist, was to extract Radium from Uranium ore. He describes the process in some detail, but what is most interesting was the attitudes at the time for this relatively new radioactive isotope. He also describes his exposure to the substance and the effects it has had on him to this day. Don is healthy, 88 years old, and shows positive for radon gas in his breath at some 25 times the regulatory limit.

Radon 226, which occurs naturally, is very long lived (1600 y) and has several decay products (Ra226 – Rn222 – Po218 – Pb214 – Bi214 – Po214 – Pb210). The decay products are all relatively short lived and show up in gamma scans of his body. Experts suggest that there is likely a large burden of Radium in his body, probably in his bones, and is unlikely to change. So what does this mean?

A 1994 study at Argonne National Laboratory (Radium in Humans) looks at the history of Radium and those who used it or worked with it. In the early 1900s Radium was used for medical treatments for such ailments as arthritis, and was also sold as a drink to members of the public as a "tonic" for good health. One popular brand was Radithor, available as a drink, a bath or for external use as a compress.

It was commonly used by clock and dial painters to give luminescence to the dials, and was hand painted using fine paint brushes, often wetted by mouth to make the "paint" apply better. These workers acquired high burdens of Radium in their bodies. However, the studies indicated that only those with a body burden between 1.2 and 23 micro-curies developed symptoms, and the National Committee on Radiation Protection determined in 1941 that a maximum tolerance level of 0.1 micro-curie would be safe.

Don's personal memoir is both interesting and fascinating, and is another example for questioning the validity of the commonly held Linear-No-Threshold theory applied in present day radiation protection, and still forms the basis for current radiation protection regulations.



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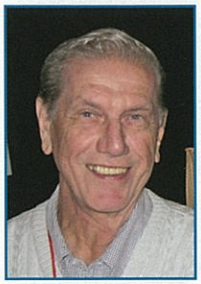
In This Issue

The lead article in this edition is the report on the 2014 Conference and Trade Show of the Canadian Nuclear Association, held in the Westin Hotel in Ottawa, February 26 – 28, 2014, which attracted more than 700 delegates and was used by government officials to make a number of important announcements. We are also honoured to have a personal memoir by Don Wiles of his 1947 experience working with Radium at then Eldorado Mining and Refining in Port Hope, Ontario. We thank Don for sharing his personal experience.

Three technical papers from the 12th International Conference on CANDU Fuels are included (Proceedings from the September 2013 conference has now been issued).

General News and CNS news contains a number of interesting items, and of course Jeremy Whitlock's Endpoint with his usual informative and satirical take on our industry.

At press time we are still waiting for spring to arrive; hopefully the weather will be more pleasant when you are reading this Bulletin!



The Society

An important milestone was passed in February when the Canadian Nuclear Society received official notice that its application for Continuance under the relatively new Canada Not For Profit Corporations Act had been accepted by Industry Canada. A report on that exercise is included in the CNS News section of this issue.

CNS Secretary Colin Hunt deserves credit for handling the extensive communication about By Law changes with the legal firm the Society engaged to help us through this transition.

Much effort continues to be extended on the two major events the Society is holding this year – the *10th International Conference on CANDU Maintenance* being held in Toronto, May 25 – 27 and the *Pacific Basin Nuclear Conference (PBNC)* in Vancouver, August 24 – 28.

The Maintenance Conference is being spear-headed by 1st Vice-President Jacques Plourde, who will be ascending to President at the Annual General Meeting being held on the Sunday afternoon, May 25, immediately before the beginning of the conference. Given the aging of our nuclear power plants, thorough maintenance is essential if the operating units are to continue operating as well as they have been doing.

The organization for PBNC is steaming ahead under the expert and energetic leadership of former CNS president, Frank Doyle, and his co-leader, Bill Kupferschmidt, vice-president at Atomic Energy of Canada Limited. They now have over 400 technical papers (up from the 300 reported in the December issue) and a long list of plenary speakers from most of the countries represented on the Pacific Nuclear Council, the authorizing organization for the PBNC series.

Although PBNC 2014 is aimed at an international audience, the Society, and its partner, the Canadian Nuclear Association, have decided to hold their *38th CNS / CNA Student Conference* within PBNC 2014.

In addition there are some smaller events, The earliest is the *Canada-China Conference on Advanced Reactors* being hosted by CNS at Niagara Falls April 27 -30. A third *Technical Meeting on Small Reactors,* jointly sponsored by CNS and AECL will be held November 5 – 7 in Ottawa.

The Nuclear Scene

The state of nuclear power programs around the world is very mixed. China and India both have major programs for additional nuclear power plants an Japan is edging towards restarting many of its nuclea units that have been shut down since the Fukushim catastrophe of just over three years ago.

However, the European Union appears to be dom nated by "renewable energy" devotees who are propo ing policies which will limit or reduce the number c nuclear power plants. The US nuclear program is cu rently struggling against the very low price of natura gas resulting from the remarkable success of the fracl ing process.

Here in Canada there is both good and questionabl news.

Possibly the most encouraging news was the start-up c the Cigar Lake uranium mine in Saskatchewan after yea of wrestling with a very complex geological problem. Th ore of that mine is reported to be the highest percentag of any uranium mine in the world. (There is a short new item on Cigar Lake in the General News section.)

The federal government has taken a further step towarc having the AECL's Chalk River Laboratories managed by private consortium by inviting specific proposals.

From the official statements and comments by th Minister of Natural Resources, Joe Oliver, the gover ment expects this "GO-CO" (Government Owne Contractor Operated) arrangement will significantl decrease the cost to Canadian taxpayers, referring t the example of the nuclear laboratories in the US/ However, at a CNA Conference a couple of years ag the heads of two large US laboratories, Idaho an Savanah, both said that their greatest source of func was still the federal government, but from many diffe ent departments and agencies instead of formerly ju the Department of Energy.

In this context, in a private discussion a coup of years ago with the deputy head of the Idah Laboratory, he commented that a third of his budg that year came from Inland Security !

In Ontario, the Minister of Energy, Bob Chiarell has reiterated the (current) provincial government support for the refurbishment of the Darlington unit However, with a provincial election expected soon may be sometime before the position of the new go ernment is known. Further, with a new Chairman ju appointed for the Board of Ontario Power Generatio and new appointments to the Board to be announce soon we face a possible repeat of the fiasco when Bc Rae appointed Maurice Strong chairman of Ontar Hydro three decades ago.

Remember the saying – What will be, will be.

F.

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~ Cover Photo ~

Workers in the final stages of refurbishing the Bruce reactors.

Photo courtesy of Bruce Power

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

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

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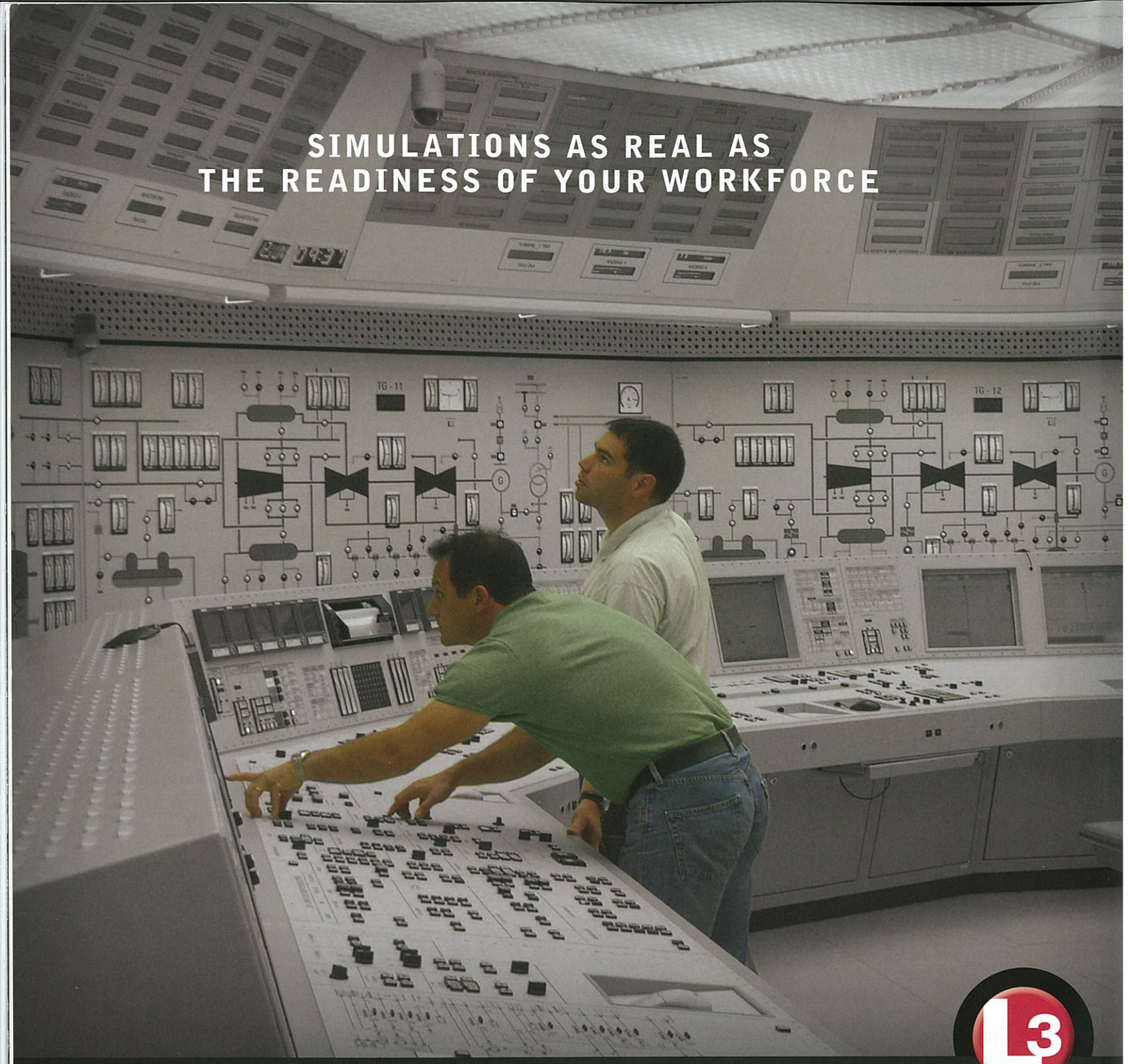
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CNA Conference and Trade Show

Federal and Provincial Ministers Express Support for Nuclear Power

by Fred Boyd

The *2014 Conference and Trade Show of the Canadian Nuclear Association*, held in the Westin Hotel in Ottawa, February 26 – 28, 2014, again drew over 700 delegates of government ministers and officials, business and academic leaders and representatives of most of the companies involved in the Canadian nuclear program. Fitting with the theme of *Developing the Next Generation*, among the delegates were 100 students sponsored by CNA member organizations, most of whom participated in a tour or the Chalk River laboratories on the Tuesday.

The event began officially with the opening of the trade show and a reception on the Wednesday evening.

There were, however, two Workshops in the afternoon; one on *Policy and Communications* the other on *Regulatory Affairs*.

As has been a pattern over the past years, government ministers and senior representatives of major organizations involved in the Canadian nuclear program chose the annual CNA Conference to make significant announcements.



The first speaker on the Thursday morning was **Joe Oliver**, Minister of Natural Resources Canada

He began by emphasizing the Government of Canada's ongoing support of the Canadian nuclear program. In line with the conference theme *"Developing the Next Generation,"* he praised the industry's accomplishments and spoke about the opportunities facing Canada's nuclear sector. The Minister highlighted the recently signed Nuclear Cooperation Agreement with India, the Supplemental Protocol to the existing Nuclear Cooperation Agreement with China, and the proposed uranium trade liberalization measures in the Canada-EU Trade Agreement.

The Minister also discussed government current initiatives, including:

- Introducing the Energy Safety and Security Act in Parliament, which increases the absolute liability of nuclear facility operators from $75 million to $1 billion for injury and damage;
- Committing $222 million over five years from Economic Action Plan 2014 to support research at the TRIUMF facility, which has had promising results in producing the medical isotope Technetium-99m;
- Providing $117 million over two years to the Chalk River Laboratories of Atomic Energy of Canada Limited, to ensure safe and reliable operations and a secure supply of medical isotopes; and,
- The ongoing restructuring of AECL which is now moving toward a government-owned, contractor-operated model for its nuclear laboratories.

Although he did not remain at the podium for questions from the audience he was surrounded by a "scrum" of media representatives as soon as he left the room. That did result in some articles in mainstream newspapers.

There were two more political leaders on the program on the Friday morning; **Bob Chiarelli**, Ontario Minister of Energy, and **Kevin Sorenson**, federal Minister of State for Finance. *(See their comments later.)*

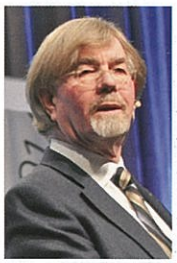


Following Minister Oliver's opening address, **Duncan Hawthorne**, CEO of Bruce Power gave one of his impassioned addresses, without notes as usual.

He began by noting that when Bruce Power first leased the units at the Bruce site there were very few employees under 35. That has changed, he stated, through constant hiring. "We are here to stay", he emphasized and stated that Bruce Power is prepared to make significant investments in the Bruce units, even though they are leased from Ontario Power Generation.

Referring to public perception, he acknowledged that splitting atoms is difficult for many to understand. More important in relationships with the public, he said, was how those associated with the nuclear plants behave. Therefore Bruce Power searches for values when recruiting new employees. Standards are much higher now than just a couple of decades ago, he asserted.

In closing he asked those in the audience to raise their hand if they expected to be still working in 2030. Very few hands went up.



Related to the aging question the next speaker was an academic from a completely different field – demographics. **David Foot**, author of *Boom, Bust and Echo – profiting from demographic shift in the 21st century*. With a flood of slides he presented data on the age distribution of populations of various countries. Much depends on fertility, he said, and commented that of the USA is much higher than Canada's, due mostly to the Spanish and black segments.

Most of Europe has a declining birth rate except for France, he noted and the populations of Russia and

Japan are shrinking and aging. He closed with a comment that aging societies use more electricity – for heating in the winter and cooling in the summer,

Rounding out the morning was a three-person panel discussing the key skills needed for a successful nuclear future in response to questions posed by a moderator. The panelists were: **Pierre Tremblay**, president of Canadian Nuclear Partners; **Jim Rippon**, president of AMEC-NSS; and **Jerry Hopwood**, vice-president Candu Energy.



Rippon began by noting that there had been a number of changes in the workforce but was confident that the various organizations involved in the Canadian nuclear program can develop the skills needed. Hopwood referred back to the talk by Duncan Hawthorne and his emphasis on investing in the workforce. Candu Energy, he commented, is also bringing about a younger workforce through hiring, including a number from other countries. Their median age is now about 40. Tremblay noted that Ontario Power Generation, his company's parent, has been hiring for 30 years.



The special after lunch speaker was **Gwyneth Cravens**, author of *Power to Save the World: the Truth about Nuclear Energy* and a co-star of the video *Pandora's Promise*.

She began by showing photographs taken from space taken of earth at nighttime. America, Europe, and parts of other continents were bright, while much of Africa and the mideast were dark. The billion people who live in those areas have no electricity, she stated. Nuclear power is the best answer, she asserted, and noted that it currently provides 17 per cent of the world's electricity. Of the various sources of electricity nuclear has the least deaths per megawatt produced, she said.. However, she noted that a number of nuclear critics who describe themselves as environmentalists have raised fears, which the general media spreads. In closing she quoted Deepak Chopra that "If it scares, it airs".

The afternoon session began with a panel of Chief Nuclear Engineers from the three utilities with nuclear plants: **Alnoor Bhaloo**, New Brunswick Power; **Frank Saunders**, Bruce Power; and, **Mark Elliott**, Ontario Power Generation, discussing *The Next Level of Nuclear Safety* again in response to topics posed by the moderator.



They all noted the development of enhanced response plans in which they try to anticipate possible external events. Elliott mentioned a major "drill" to be held this summer in Ontario which will involve many parts of the provincial and municipal governments. Newman commented that Bruce Power has extensive engagement with the local civil administration. An unplanned loss of the grid can cause a number of actions at the plant, he noted, which need to be explained quickly. At Point Lepreau, Bhaloo said they continually try to improve the public's trust in their operation.

The next speaker was, **John Barrett**, the new president of CNA, who spoke on *International Opportunities for Canadian Knowledge*, drawing on his background as Canada's Ambassador to the International Atomic Energy Agency and Chair of the IAEA's Board of Governors.

Noting that Canada has a permanent seat on the IAEA Board of Governors, he commented that the country is well respected internationally. A challenge is how to build on this international reputation. In this context he applauded the recent mission to India by representatives of the Organization of Candu Industries. There should be more government to government relations, he said, adding that political backing is needed. In closing he noted that the CNA will be holding a workshop on exporting.

Before the final panel of the day, **Bill Kupferschmidt**, presented a short but effective advertisement for the **Pacific Basin Nuclear Conference 2014,** to be held in Vancouver, August 24 – 28, 2014. This conference, sponsored and organized by CNS, CNA and Natural Resources Canada, is a great opportunity, he said, to show Canada's capabilities to many senior representatives from countries around the Pacific. *(See ad in this issue of the Bulletin.)*

Rounding out the afternoon program was another panel, on the topic, *How Will Small Modular Reactors Impact the Next Generation.* The panelists were: **Peter Lang**, president of Dunedin Energy Systems; **Robin Rickman**, Director of SMR Projects, Westinghouse Electric; and **John Ferrara**, Director of Business Development, Generation mPower LLC.

Ferrara began by showing slides depicting the significant size difference of their proposed small modular reactor to a typical large PWR unit. Lang commented that his focus is on Canada's north and arctic areas



where there are many small communities and mines currently depending on expense diesel fuel. For such purposes he proposed a 30 MW(th) (6 MWe) remotely-operated unit with a 25 year life as the typical requirement. Rickman noted that Westinghouse is focussing on units of 225 MWe built in modules which could be erected on site in a year and a half. His company is expending a major effort on SMRs and expects to spend up to 18,000 man-years on design, development, and regulatory approval before the first unit is installed.

After noting there are time constraints for shipping to the north Lang commented that there is a great need to convince those living and working in the north of the feasibility of using nuclear power.

That evening there was an extensive Trade Show reception. Bruce Power hosted a dinner in the near-by government conference centre with about 200 invited guests.



Following breakfast on the Friday morning, **Taylor Wilson**, just 20 years old, gave a fascinating overview, without notes, of the nuclear experiments he had pursued from the age of 10. He, reportedly, produced a fusion reaction at the age of 14, at the University of Nevada-Reno.

After showing slides of his experimental equipment he offered comments on different aspects of the current nuclear scene. He said he believes in the future of small, medium reactors and in the use of nuclear plants for desalination. Regarding outreach, he suggested that the nuclear community should focus on the high school generation.



The first formal presentation was by **Michael Binder**, president of the Canadian Nuclear Safety Commission, who began by noting the number of hearings the Commission has held outside of Ottawa. He commented that the past few months had been very active ones for the CNSC. Internationally, agreements were concluded with India, China and Kazakhstan and the Commission was involved developments on the Convention on Nuclear Safety and the IAEA report on Fukushima. Domestically, there was the closure of Gentilly 2; the Ontario Long-Term Energy Plan and the relicensing of several uranium mines.

On the issue of moving nuclear material, which has evoked much media and public reaction, he noted that there are many shipments of radioactive isotopes conducted safely every day. For 2014 the Commission anticipates a number of issues; including court challenges, consideration of the hold-point for Pickering NGS, the 6th meeting of the Convention on Nuclear Safety, the restructuring of AECL, and a major simulated nuclear plant accident test. As well, the CNSC is looking at longer licence terms for nuclear facilities.

In closing he noted that there had been disruptions at several of its meetings. "We will not tolerate that", he stated, "and are examining the best way to control it".



Next was **Joan Miller**, Vice-President, Waste Management, AECL, addressing the topic *Nuclear Waste Management: The Way Ahead.*

With the program for high-level legacy waste well under way, AECL is turning its attention to low-level waste. This presents a different challenge, the much larger volume, she mentioned. A focus will be on minimizing the amount needing long-term management.

On decommissioning she referred to a recent OECD report and invited companies to partner with AECL in developing solutions.



Bob Chiarelli, Ontario Minister of Energy gave his government's perspective. He noted that nuclear power provides the bulk of Ontario's electricity. However there have been changes in the projections of needed generation, he commented. The growth of hi-tech industries replacing the energy intensive ones has resulted in less demand for electricity which led to his government's difficult decision to cancel the planned new units at Darlington. However it supports the refurbishment of the existing Darlington units.

Another panel discussion followed, on the topic *Attracting Top Talent to Canada's Nuclear and Uranium Sectors.* The participants were: **Michelle Branigan**, CEO, Electricity Human Resources Canada; **Sue Ivey**, Director of Recruiting, Calian Technologies; and **Alice Wong**, Senior Vice-President, Cameco Corporation.

They began on the matter of knowledge transfer



from retiring staff to new ones. Branigan commented that many of those approaching retirement were reluctant to pass on the special knowledge that had gained over the years. It is important to deal empathetically with pre-retirees, she added. Wong noted that nuclear is hardly mentioned in school curricula so few young people are aware of the opportunities.



The final speaker was **Kevin Sorenson**, federal Minister of State for Finance, who spoke mostly about the broad economic plans of the federal government. Canada's economy is the strongest among the G 8 countries, he asserted. Regarding training he said the government and industry support apprenticeships but only about half of those who begin finish the program. The federal government provides support for those in training, he added, with industry deciding what is needed.

With the formal program completed, CNA President, John Barrett, closed the event with thanks to all of the participants and invited all the remaining delegates to enjoy the lunch being served in the exhibit area.

(Photos of speakers are courtesy of Alex Wolf of CNA.)

Scenes from The Conference



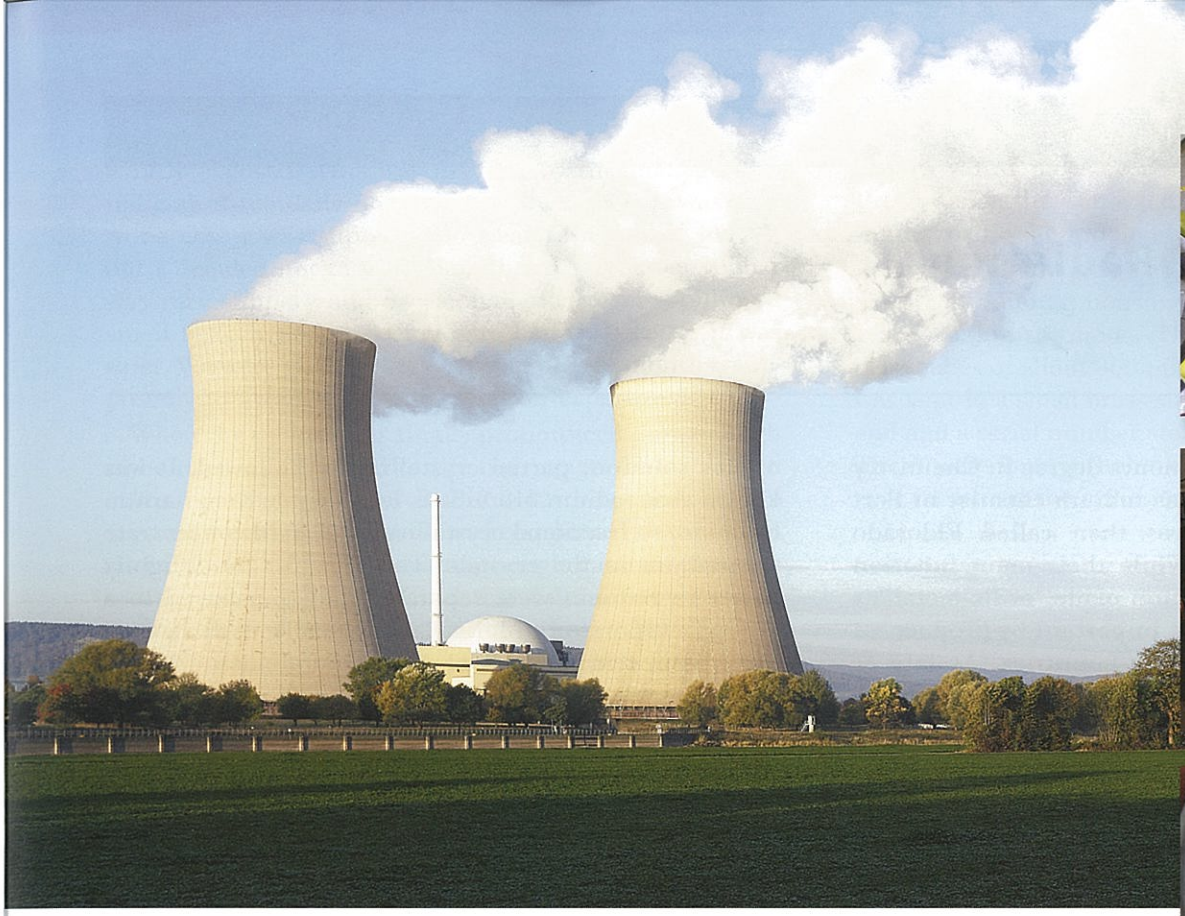


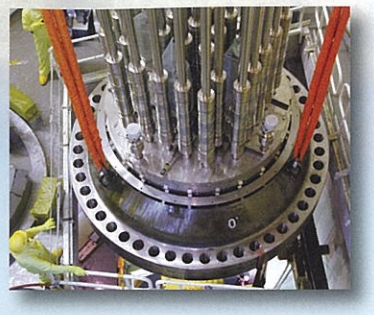




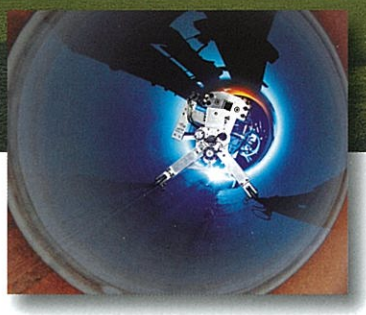
















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On Radium and Radiation

by DON WILES, Almonte, Ontario

On graduating with an Honours degree in Chemistry in 1947, I was offered a job as radium chemist in Port Hope, Ontario, in what was then called Eldorado Mining and Refining Co. While their main function was the production of Uranium oxide, or "x-metal"as it was called, Radium was an important by-product, to be exported to many European countries. As late as the1950s, artificial radioactive isotopes (technetium, cobalt and others) were not yet available for medical uses. Instead, Radium was used exactly as Marie Curie had done decades earlier. This meant that Radium had to be extracted from the Uranium ore and purified for use. Ultimately the radium, in platinum 'needles' about 5 mm diameter by about 3 - 4 cm long, was surgically inserted into cancerous locations, with the idea that the radiation would destroy the cancer.

I was to be employed in the radium finishing lab, which meant purifying radium for subsequent packaging in platinum needles for ultimate use in treating cancers. I was to be number three in a small group in which the group leader had been temporarily given leave because of a serious radiation burn on his abdomen. It seems that someone had put about 2 - 300 milliCuries of radium in his lab coat pocket and he hadn't known that. After some days, the pocket fell off the jacket and he began to notice the burn.

It is perhaps worth noting that radium decays through a series of 'daughters' – initially called radium A, radium B and so on. Radium D is now known to be Lead-210. Since pure radium-226 emits only short-range alpha particles, it is not particularly dangerous as long as it remains outside the body. The dangerous radiation comes only after a few days of build-up of the daughter products, notably radon-222 and the subsequent lead-214 and bismuth-214. Thus, while a freshly crystallized sample containing radium doesn't appear to be radioactive, after a week it becomes very radioactive, easily measurable and much more dangerous even outside the body.

Before it was transferred to our group, the radium had been separated from the uranium ore as the insoluble radium carbonate, along with added barium as carrier. This carbonate was then dissolved in a hydrobromic acid solution and subjected to crystallization in large glass bowl- shaped evaporators, about 5 feet in diameter. On partial evaporation and then cooling of this solution, partial crystallization followed. It was known that radium bromide is less soluble than barium bromide, so fractional crystallization would concentrate the radium in the crystals. The crystals, now slightly richer in radium, were separated and transferred to a second evaporator. (Marie Curie usually used radium chloride in this same way.) After several such evaporations, the crystals were moved to another section of the lab and crystallized several more times, now in quartz bowls about 18 inches in diameter.

The crystals were then taken to the 'flask lab' where a feeble old guy performed yet more crystallization to produce crystals that were by then much more concentrated in radium. Finally, this crystalline mixture of barium and radium bromides was transferred to me in the purification lab. Each month I was given about 8 Curies of radium, along with a lot of barium. It was then my task to crystallize this mixture many more times – first in beakers of about 100 mL, and later in quartz crucibles of perhaps 20 mL capacity. This was all done in a ventilated fume hood with a thick lead shield protecting some parts of my body. The final crystals were deemed 'pure' if they were measured to be over 80% radium bromide.

This whole crystallization process, done exactly as Marie Curie had done 50 years earlier, was interesting and was, I now know, quite hazardous. Heating to evaporate the solutions led also to the evaporation of the radon, so the solutions did not appear to be very radioactive. However, each Monday morning, after a weekend of not being heated, the daughter products had accumulated in the solutions. By then, the intensity of the radiation was such that the beakers were distinctly brown and in the later stages quite dark brown from radiation damage to the glass and the quartz. This damage was readily 'annealed' on gentle heating. There was often a week or so delay before our colleague tottered in with another flask containing a new batch of 8 Curies.

There was a 'health inspector' who came around occasionally and pointed his radiation monitor, called a "super Lilly", at the beakers and found no radiation. He didn't seem to know that freshly-heated solutions of radium emit only alpha particles, which his monitor couldn't detect.

The gamma emitters were up over our heads in the ventilation duct, which he didn't monitor. I was required to wear a radiation badge waist high on my lab

coat, well protected by the lead shield. This badge was measured every day, and was usually found to be black – fully exposed. This was deemed by the managers to indicate three daily doses of radiation, which was said to be OK. I was supposed to wear thin rubber gloves, but I decided not to wear them because the wet rubber was very slippery and occasionally led to my spilling a small beaker. So I used my bare hands, because it was safer. We were given a week off every three months, supposedly to average out our radiation exposure.

When the radium was finally pronounced pure enough to be used, it advanced to the next stage. This involved calcining the bromide (RaBr2.2H2O) to remove the crystalline water, because it was considered that radiolysis of the water might lead to enough gaseous pressure to cause an explosion. I did this calcining by heating the crystals over a small flame, and saw that the now anhydrous radium bromide glowed in a very lovely pale mauve colour. The anhydrous crystals were now passed to a colleague, whose job is was to grind up the solid to a fine powder and put it into small glass tubes. This was all done in the fume hood, but the ventilation was turned off, in case any of the powder might escape. (Radium was then worth $20,000 per gram.) The glass tubes had been weighed when empty, and it was now my job to weigh them again and seal the tubes in a flame. This was done in the open lab, not in the fume hood. We were told (verbally only) not to do this operation if any Provincial health inspectors were in the plant (they never came anyway).

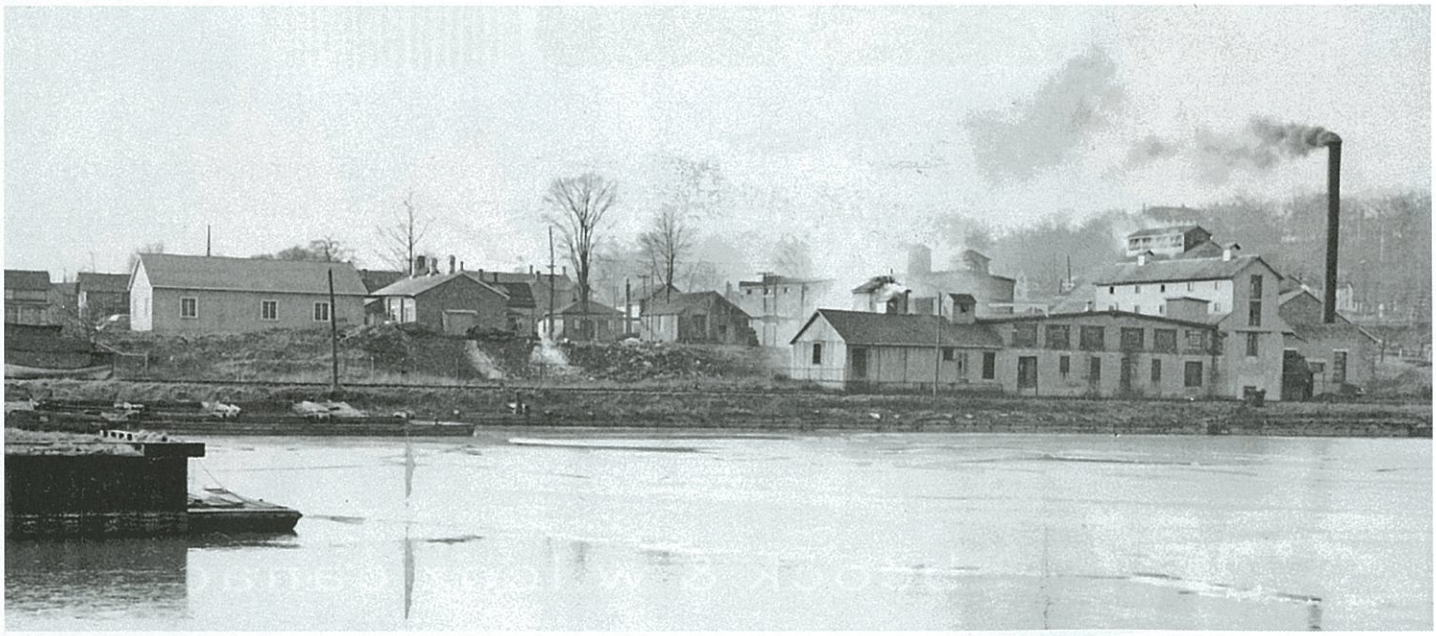
Well, it often turned out that some of the radium powder had become stuck to the outside of the glass tube. On being heated during the sealing, this radium usually flew up into the air, and showed the radium 'flame test'. The colour is a strong red, very like that of lithium. I occasionally wonder how many others in the world have ever seen the radium flame test. Presumably, this same radium, now in the atmosphere, would readily be inhaled by the nearest chemist – me.

Another of my jobs was to be in charge of the vault – a small building housing some hundreds of Curies of 'pure' radium bromide. The radium was now in small glass tubes of about 300 millicuries each. Each little tube was kept in a small brass sleeve with a screw plug in each end and a serial number stamped in the side of the brass. These were kept in holes drilled in lead blocks. No one ever measured the radiation level in the vault.

At one time a prominent Director of the company brought in a canvas bag of diamonds. He had heard that radiation might make diamonds sparkle more brightly. My task was to take one vial at a time, read and record the serial number and put it into a large lead pot – about 75 Curies total – and then put the diamonds on top. This was now old radium, up to its maximum in radiation, so I must have received a very large dose. A few weeks later, the process was reversed, and I put each vial back in its proper place. I never looked at the diamonds.

Worked at this job for about 16 months before moving on to Graduate School. One could now imagine that all this radiation must have seriously damaged my health. Not so, in fact. About 65 years later, I am still healthy.

Dr. Don Wiles is Emeritus Professor of Chemistry at Carleton University in Ottawa. Among his publications are two recent books: "The Chemistry of Nuclear Fuel Waste Disposal" and "Radioactivity: What it is and What it Does" published by Polytechnic International Press in Montreal.



View of the former Eldorado Mining and Refining Co. from the 1930s

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Flawed Engineering Input to Ontario's Long-Term Energy Plan

by DON JONES

The input from the Ontario Society of Professional Engineers (OSPE) to the Ontario government's 2013 Long-Term Energy Plan (LTEP) supported the government's Community Energy Plan (CEP) program and wanted more flexibility from the nuclear power plants (reference*).

From the Ontario government's News Release (reference*) the purpose of the CEP program is to assist municipalities and Aboriginal communities to reduce greenhouse gas (GHG) emissions and promote conservation and "clean energy". CEP seems just another way of promoting frackgas-fired distributed generation that is promoted by the gas/wind "clean air" lobby and now apparently by OSPE.

A typical urban municipal energy system promoted by OSPE could consist of gas-fired boilers supplying a district heating system augmented by waste heat from the gas-fired reciprocating engines of a combined heat and power (CHP) plant that could be generating some of the electricity to run the energy system. The energy displaced by the gas-fired district heat/CHP plant could be mostly gas or electricity. If gas, reductions, if any, in GHG emissions from district heat/CHP operation would come from waste heat from the engines and will not come from the electricity generating portion of the CHP plant. This is because Ontario has one of the lowest GHG emitting power grids in the world with nuclear and hydro meeting about 80 percent of its annual demand. If electric heat were displaced GHG emissions would increase. CHP systems alone could be used to provide heat and power to large institutions, like hospitals. However a district heating/CHP system that uses gas produces GHG emissions and is vulnerable to short and long term fuel shortages and to the inevitable increases in frackgas prices (reference*).

OSPE "supports the government's commitment to a balanced approach for an affordable, reliable and sustainable electricity system". Unfortunately the electricity system will not be affordable, reliable and sustainable (reference*). Also, "OSPE recommends improving the flexibility of nuclear units to enable effective use of additional variable renewables that have already been contractually committed". OSPE has not condemned unnecessary, unreliable, and expensive wind/solar (and hence gas) on the Ontario grid and accept it as a given that has to be lived with by reducing the output of nuclear stations so that it can be accommodated. At the very least OSPE should argue against more wind on the grid. Flexible nuclear stations should be used to accommodate more flexible nuclear on the grid not more wind (reference*). Reducing low cost GHG-free output from nuclear plants to accommodate high cost wind generation makes no environmental, economic or technical sense. OSPE supports gas-fired district heating systems and CHP systems that will, supposedly, "relieve stress on the large electricity infrastructure". This is only true if the displaced heat loads were electric, and not gas, but then GHG emissions will increase with gas district heating. OSPE states that a reduction in the nuclear portion of the energy mix will cause GHG emissions to rise because of the need for "gas-fired backup that will be required to make renewables work reliably until cheap storage becomes commercially available". It would make more sense that storage, if this silver bullet ever came, be used with the nuclear stations, rather than with unnecessary, unreliable wind/solar, so that nuclear could run at full power all the time.

Ontario should be transitioning to a nuclear/hydro electricity supply. Clean electricity from nuclear and hydro stations must be used to drive efficient ground source heat pumps that could supply the same heating and cooling loads as the district heating/CHP systems being promoted by OSPE and the CEP program. Thermal storage for heat and cold could make use of low cost off peak nuclear/hydro electricity. Present nuclear electricity costs are lower than gas and electricity from new build nuclear will be competitive in price and, unlike frackgas, little affected by fuel price hikes. With climate change likely to cause more extreme weather events Ontario needs its own secure long term electricity supply.

Having gas provide both heating and electricity through Ontario's cold winters is a life and death issue. Ontario should be building more nuclear stations and strengthening its transmission and distribution infrastructure with modern equipment, reinforcement, redundancy and remote monitoring of field equipment to make it more resistant to failures. The transmission/distribution grids should be robust enough to tolerate equipment outages due to failures and maintenance without significant loss of reliability and be more resistant to common mode events like extreme heat, ice storms, high winds, and flooding. This would be the real "smart grid" not the one that is costing billions of dollars to tie-in all those unnecessary wind turbines, solar panels and smart meters. Money and resources must not be diverted from this important long term task by short term, dead end, planning. There is no long term future in gas and wind.

*For full version and references see item 35 of, http://thedonjonesarticles.wordpress.com/articles/

Post-Irradiation Examination of the 37M Fuel Bundle at Chalk River Laboratories (AECL)

by J. ARMSTRONG[1], T. DANIELS[2] and J. MONTIN[1]

[Ed. Note: The following paper was presented at the 12th International Conference on CANDU Fuel, held at the Holiday-Inn Waterfront Hotel, Kingston, Ontario, 15-18 September, 2013.]

ABSTRACT

The modified 37-element (37M) fuel bundle was designed by Ontario Power Generation (OPG) to improve Critical Heat Flux (CHF) performance in ageing pressure tubes. A modification of the conventional 37-element fuel bundle design, the 37M fuel bundle allows more coolant flow through the interior sub-channels by way of a smaller central element. A demonstration irradiation (DI) of thirty-two fuel bundles was completed in 2011 at OPG's Darlington Nuclear Generating Station to confirm the suitability of the 37M fuel bundles for full core implementation. In support of the DI, fuel elements were examined in the Chalk River Laboratories Hot Cells. Inspection activities included:

- Bundle and element visual examination
- Bundle and element dimensional measurements
- Verification of bundle and element integrity
- Internal Gas Volume Measurements

The inspection results for 37M were comparable to that of conventional 37-element CANDU fuel. Fuel performance parameters of the 37M DI fuel bundle and fuel elements were within the range observed for similarly operated conventional 37-element CANDU fuel. Based on these Post Irradiation Examination (PIE) results, 37M fuel performed satisfactorily.

Introduction

Life Management is imperative to maintain the safe, reliable and economic operation of CANDU reactors. As CANDU reactors age, pressure tubes experience irradiation assisted creep, resulting in flow bypass over the top of the fuel bundle. This has an effect on conventional 37-element fuel sub-channel cooling and critical heat flux (CHF) performance [1]. In 2010, Ontario Power Generation (OPG) began the demonstration irradiation (DI) of a modified 37-element fuel (37M) design at OPG's Darlington Nuclear Generating Station, which featured a smaller 11.5 mm (nominal) diameter centre element to improve bundle CHF in ageing pressure tubes [1]. Design changes made to the 11.5 mm diameter centre element included a reduction in the endcap dimensions and taller spacer pads.

The 37M DI bundles were discharged in 2011 and 2012 and examined in the Darlington irradiated fuel bays. Elements were removed from 37M bundles with bundle burnups in the typical operating envelope and were shipped to Chalk River Laboratories (CRL) for post-irradiation examination (PIE). An intact 37M bundle was subsequently shipped to CRL for PIE. The maximum bundle powers were between 600 kW and 800 kW (approximately 50 kW/m maximum outer element linear power).

Elements in a 37M bundle are numbered from 1 to 37 as shown in Figure 1. Element 37 is the 11.5 mm diameter centre element. At CRL, the bundle end with the manufacturer monogram on the endplate is referred to as the "Reference End" (RE) while the opposite non-monogram end is referred to as the "Non-Reference End" (NRE).

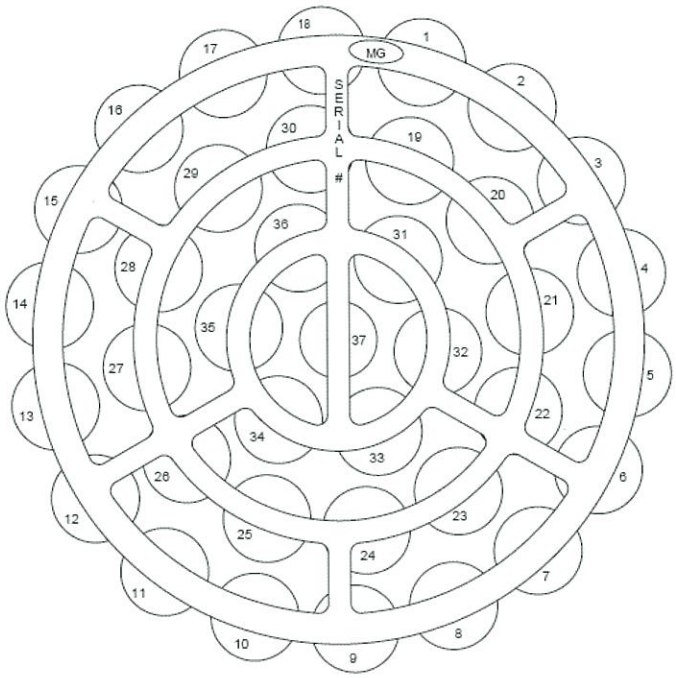


Figure 1: Element Numbering System and 37M RE Endplate Layout

1. Examination of the Intact 37M Bundle

The 37M bundle was shipped to CRL inside the Irradiated Material Transport (IMT) flask in 2011

1 Atomic Energy of Canada Limited, Chalk River Laboratories, Ontario, Canada

2 Ontario Power Generation, 889 Brock Road, Pickering, Ontario, Canada

and unloaded in AECL's Universal Cells Facility for examination. The 37M bundle was initially examined in the intact condition to assess its performance as a complete bundle. Disassembly of the bundle, required to assess the performance of individual fuel elements, was completed using a specialized milling apparatus.

1.1 Bundle visual examination

The 37M bundle and its endplates were visually examined using several inspection techniques and equipment (i.e., stereomicroscope, modified telescope and a radiation tolerant video camera). The bundle was found to be in good condition (Figure 2). Figure 3 shows an end-on examination which showed no interlocking spacer pads (interlocking spacers can affect a bundle's ability to compress during a fuelling operation). The bearing pad wear patterns and depth were typical of conventional 37-element fuel.

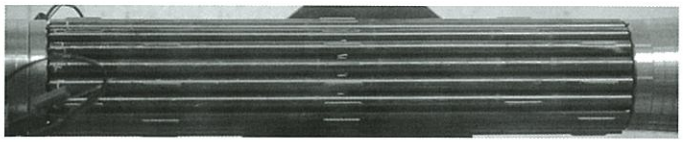


Figure 2: Intact 37M Bundle Mounted in the Profilometer Collets

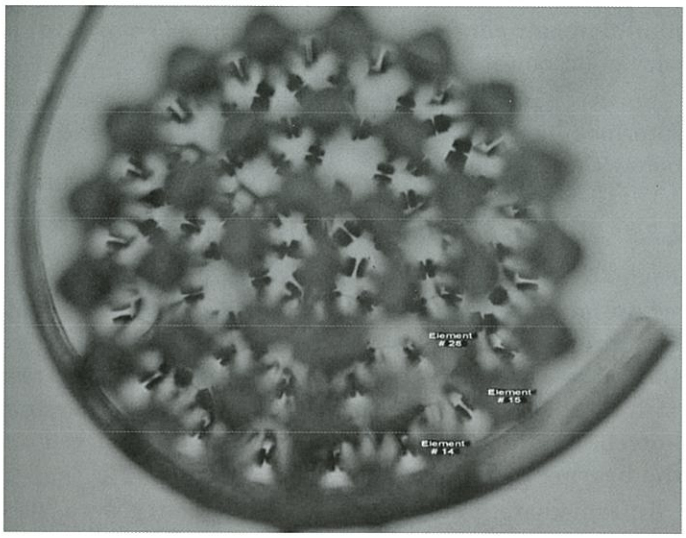


Figure 3: Inspection for Interlocking Spacer Pads

Following visual examination, the intact bundle was subjected to dimensional mensuration using a profilometer, which included bundle-element bow, element length-over-endplate and endplate distortion measurements. Bundle-element bow represents the axial deformation of the bundle by measuring displacement relative to the ends of each element. A positive bow is away from the centre of the bundle, while a negative bow is toward the centre of the bundle. Figure 4 shows a map of the outer element bow pattern. The 37M bundle conformed to the shape of the pressure tube, with elements bowing outward at the 3 and 9

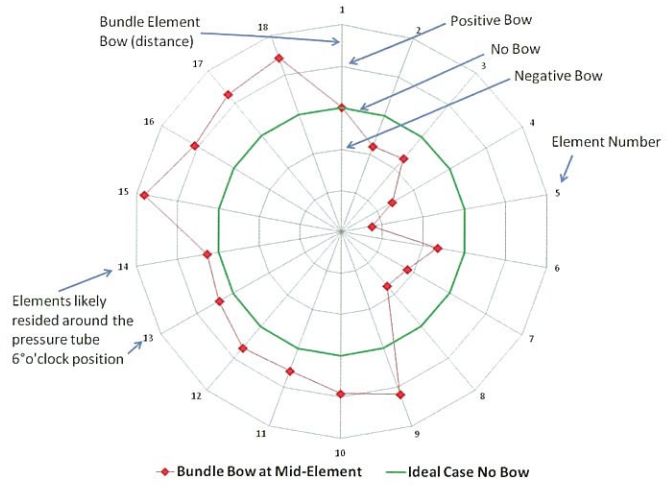


Figure 4: Bundle Bow Map

o'clock positions, while the elements at the 12 o'clock position bowed inward (i.e., 12 o'clock position represents the top of the pressure tube). The elements at the 6 o'clock position (i.e., Elements 13 and 14) generally have little bow. The bundle-element bow was comparable to previous measurements for conventional 37-element bundles ([2], [3]).

1.2 Bundle mensuration

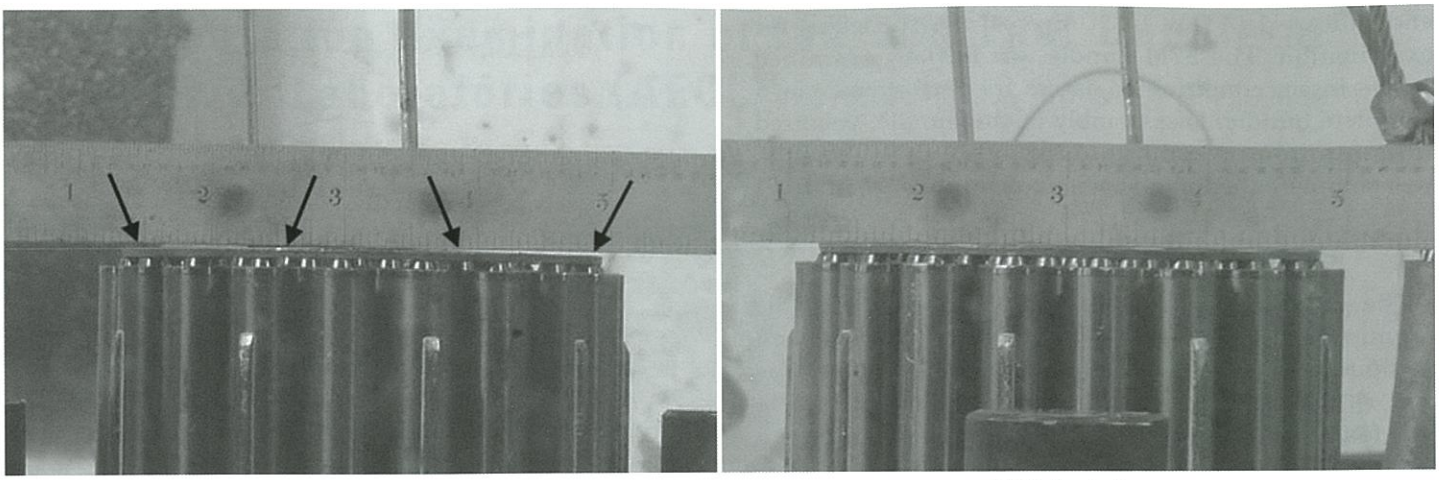
The length-over-endplate apparatus measures the endplate-to-endplate post-irradiation bundle length with respect to a calibrated standard. Lengths were recorded and averaged at locations where 36 outer, intermediate and inner elements were welded. The average bundle length was within the design specifications.

Endplate distortion is a measurement of the deformation that an endplate undergoes during irradiation. A large deformation can result in endplate cracking or loss of endplate integrity. The endplates were visually checked for distortion by placing a straight edge against the endplate, as shown in Figure 5. Fuel bundles in Darlington Nuclear Generating Station reactors are supported against the coolant flow using a latching system that contacts the downstream bundle at outer element positions. This results in slight deformation of the endplates, which support intermediate, inner and centre elements. The downstream reference endplate was domed (as expected).

Figure 5). The upstream NRE endplate was dished. The endplate distortion was within the range observed for conventional 37-element bundles irradiated at the Darlington Nuclear Generating Station.

1.3 Bundle dissassembly

The 37M bundle was placed in a supporting "clamshell" apparatus to maintain bundle integrity during the milling process. Endplate webs were cut such that the assembly welds (i.e., endcap-to- endplate welds) remained intact for incipient crack and torque testing.



RE Endplate
(Arrows Show Gap Resulting from Endplate Doming)

NRE Endplate
(Measurements Confirmed Dishing)

Figure 5: Endplate Visual Observations

2. Examination of Elements from the 37M Bundle and Elements Shipped from Other 37M Bundles

Detailed element examinations were completed on the 37 elements from the disassembled 37M bundle and disassembled elements from other 37M bundles. All elements were visually examined under a stereomicroscope and their diameters were profiled. Selected elements were subjected to endplate assembly weld torque testing. The internal gas volumes of twelve disassembled elements were measured.

2.1 Assembly weld torque testing

The assembly weld torque strength was measured by rotating the endplate material with a torque wrench while an element was mechanically restrained in a test fixture. All the measured torque strengths met the assembly weld torque specification.

2.2 Visual examinations

2.2.1 Elements from the disassembled 37M bundle

Elements from the disassembled 37M bundle were visually examined in four axial planes. The elements were in good condition. Most elements had marks, scrapes and scratches, consistent with normal handling. Minor deposits/stains were observed on some of the elements, comparable to what has been observed during past irradiated fuel PIE.

The observed sliding wear on the bearing pads for the outer elements was lighter for elements 1 through 9, which indicated that these elements resided in the top half of the pressure tube. This was in agreement with the bow measurements, which indicated that elements 13 and 14 resided at the bottom of the pressure tube.

The inner and intermediate elements were in very good condition. As expected, there were fewer handling mark, scrapes, and scratches observed in these two rings (compared to the outer elements). The 11.5 mm diameter centre element (element 37) was also in very good condition.

Spacer pad wear had no indication of spacer pad interlocking or excessive wear from vibrations and was below the design limit.

2.2.2 Disassembled elements from other 37M bundles

Several outer elements, each from different 37M bundles, were visually examined in four axial planes. In general, the outer elements were in good condition with scratches and scrapes typical of normal in-bay and hotcell handling. Typical sliding wear was observed on the bearing pads.

Intermediate, inner and centre elements were also examined and found good condition. The sheath and endcaps on the smaller centre elements appeared comparable to the outer, intermediate and inner elements. Spacer pads had wear depth well below the design limit. The assembly welds were observed free of defects.

2.3 Element mensuration

All elements from the 37M bundle and the disassembled element shipment were measured using a using a profilometer. Element diameters were measured in three orientations to a precision of ± 0.01 mm. Residual sheath strain was calculated using fuel manufacturing data and the measured diameters.

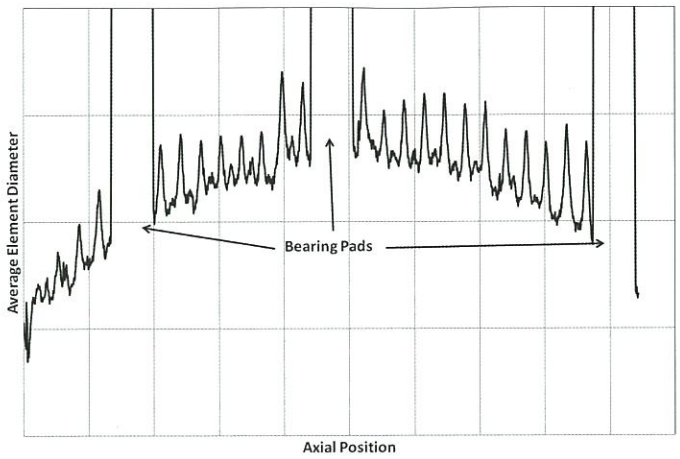


Figure 6: Example of Outer Element Average Diameter Profile

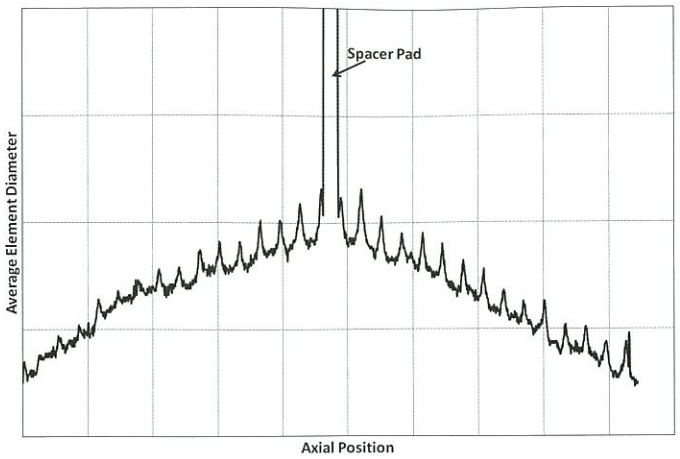


Figure 8: Example of Inner Element Average Diameter Profile

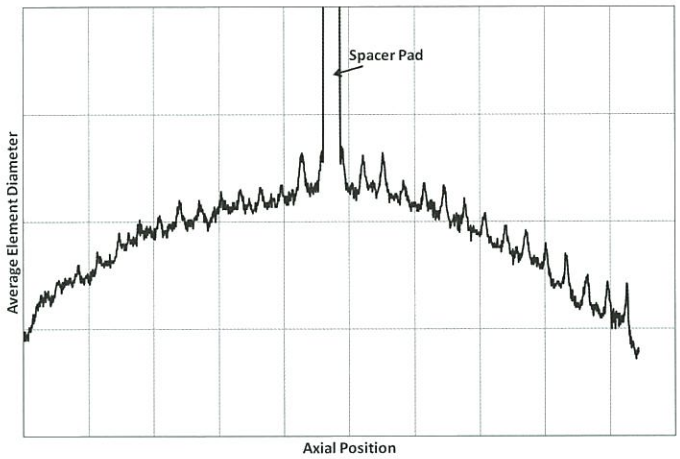


Figure 7: Example of Intermediate Element Average Diameter Profile

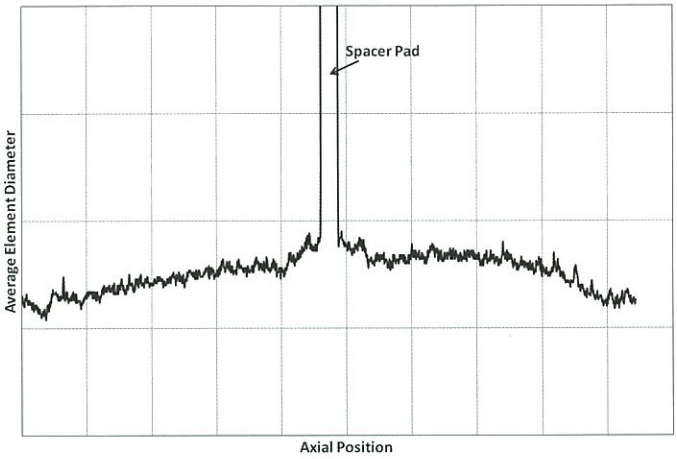


Figure 9: Centre Element Average Diameter Profile

Element centre-line bow was measured as the displacement from a straight line drawn from each end of the element. Outer element bow between bearing pad was measured as the displacement from a straight line drawn between the bearing pads.

2.3.1 Sheath diameter, strain and ridging

All elements in the 37M bundle exhibited pellet ridging, except for the centre element. Figure 6 to Figure 9 show diameter profile examples of the outer, intermediate, inner and centre elements.

Similarly, the centre elements from the disassembled element shipment did not exhibit sheath ridging. Some outer, intermediate and inner elements from the lower powered bundles had no ridging (as expected). The average residual sheath strains are within the range observed for conventional 37-element fuel. The mid-pellet residual sheath strains were within the expected operating envelope [4]. Pellet interface ridge heights were within the range of that observed in similarly operated conventional 37-element fuel.

2.3.2 Element bow

The element centre-line bow was measured at three orientations (i.e., 0°, 120° and 240°). The 0° orientation corresponds to the bearing pad plane for the outer elements and reference spacer pads for the intermediate, inner and centre elements. The largest deviation from the centre-line was comparable to that previously observed in conventional 37-element fuel.

The element bow between bearing pads was comparable to that previously observed in conventional 37-element fuel.

2.4 Element internal gas volume

The gas volumes for twelve 37M elements were measured using CRL's' custom-built FCV1000 equipment. The FCV1000 calculates the volume of gas in an element by puncturing the element in a vacuum and measuring the resulting pressure rise into a known volume. As expected, the centre (11.5 mm diameter) elements had the lowest gas volumes. The gas volumes were typi-

cal of fuel that operated to similar burnups and powers [5], and were well below the OPG operating limit [5].

3. Conclusions

One 37M DI bundle and disassembled elements from four 37M DI bundles were examined at CRL. The fuel performance parameters for the 37M fuel were within the range observed for similarly operated conventional 37-element CANDU fuel, including endplate distortion, bundle-element bow, spacer pad/bearing pad wear, residual sheath strain and element fission gas volumes. The 11.5 mm diameter centre elements fuel performance were found within the range observed for elements of that size [6]. Based on these Post Irradiation Examination results, 37M fuel performed satisfactorily.

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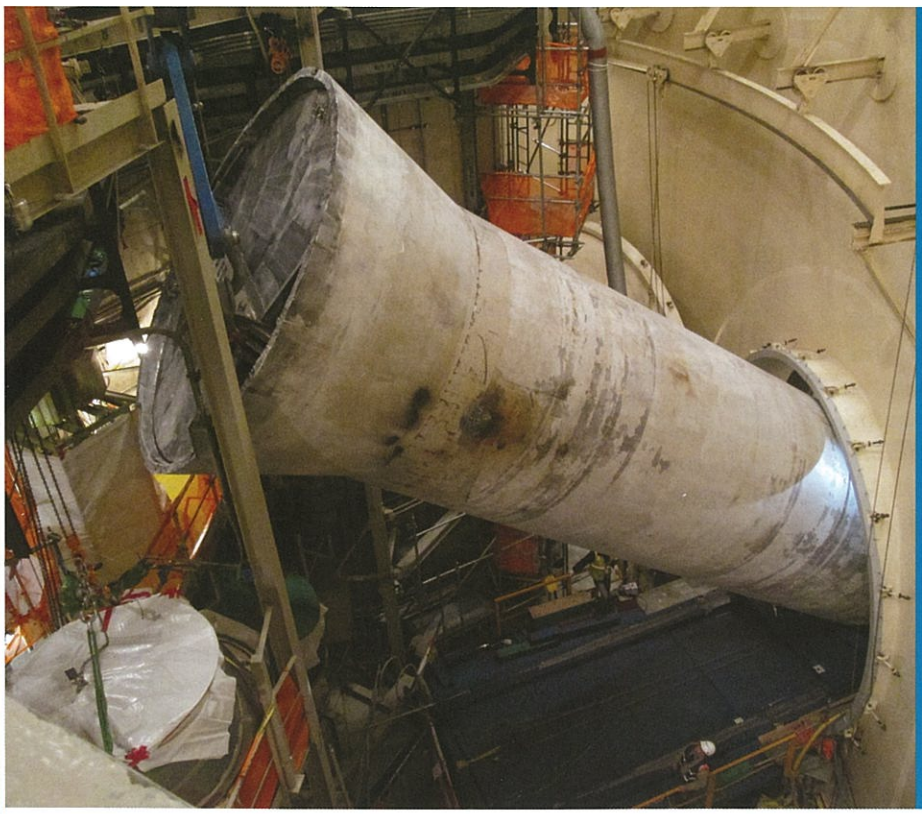
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The SLOWPOKE-2 Nuclear Reactor at The Royal Military College of Canada: Applications For The Canadian Armed Forces

by P.C. HUNGLER[1], M. T. ANDREWS[1], D.G. KELLY[1] and K.S. NIELSEN[1]

[Ed. Note: The following paper was presented at the 12th International Conference on CANDU Fuel, held at the Holiday-Inn Waterfront Hotel, Kingston, Ontario, 15-18 September, 2013.]

ABSTRACT

The Royal Military College of Canada (RMCC) has a 20 kW SLOWPOKE-2 nuclear research reactor which is used for teaching and research.Since its commissioning, the reactor facility and instruments have been continuously upgraded to develop and enhance nuclear capabilities for the Canadian Armed Forces (CAF). Specific applications of neutron activation analysis (NAA), delayed neutron counting (DNC) and neutron imaging relevant to the CAF are discussed.

Introduction

Safe Low Power C(K)ritical Experiment (SLOWPOKE) nuclear research reactors weredesigned by Atomic Energy of Canada Limited (AECL) as a simple, safe, and affordable neutron source for universities and hospitals for application of neutron activation analysis (NAA) and radioisotope production. In 1985, the Royal Military College of Canada (RMCC) commissioned a 20 kW SLOWPOKE-2 reactor into its new engineering building in support of the proposed Canadian nuclear submarine program. The nuclear submarine program never materialized but the SLOWPOKE-2 has proven to be an extremely versatile and valuable asset for RMCC and the Canadian Armed Forces (CAF). In addition to continuing to successfully conduct NAA as per its original design intent, RMCC has significantly upgraded the facility and instruments to develop capabilities such as delayed neutron counting (DNC) and neutron imaging, including 2D thermal neutron radiography and 3D thermal neutron tomography. These unique nuclear capabilities have been applied to relevant issues in the CAF. NAA at RMCC is used to investigate the elemental content of soil from small arms ranges (SARs). DNC is used to enhance the nuclear forensics capabilities of the CAF,through the identification of special nuclear materials (SNMs). Neutron imaging is used to inspect flight control surfaces (FCS) of the CF188 Hornet for water ingress and structural degradation.

1. Design and Construction

The aluminum container for the SLOWPOKE 2 reactor core is suspended in a water filled pool, which has a diameter of 2.46 m and a depth of 5.87 m. Both the reactor container and the pool are filled with light de-ionized water. This water provides cooling, radiation protection and acts as a moderator for the critical assembly. The core has a total of 198 fuel pins with Low Enriched Uranium (LEU) fuel (19.89% U-235). The fuel pins are arranged vertically inside a beryllium assembly. The beryllium acts as a neutron reflector and the annulus contains five inner radiation sites. Any of the four inner irradiation sites or the three appropriate outer sites may be used to irradiate samples for the DNC.

In order to provide a higher neutron flux for neutron imaging, an outer irradiation site was replaced (before reactor commissioning) by a thermal column containing heavy water between the beryllium annulus and the reactor container as shown in Figure 1. At half power, the thermal neutron flux measured at the location adjacent to the heavy water column is 2.7 times greater,[1]1.4 $\times 10^{11}$ n cm^{-2} s^{-1} compared to 5.1×10^{10} n cm^{-2} s^{-1} measured at the reactor container wall at a different radial location[2].

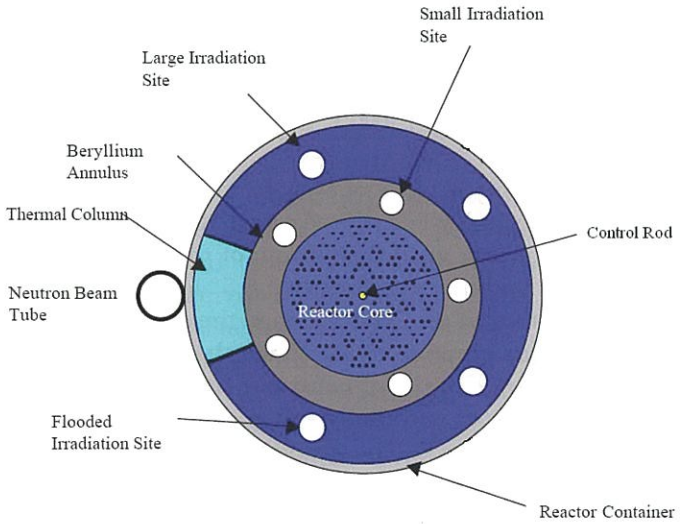


Figure 1: Cross Section View of RMCCs SLOWPOKE-2 Reactor Core

A Neutron Beam Tube (NBT) was installed in the reactor pool to permit neutron imaging. When neutron imaging is not being conducted, the NBT is positioned

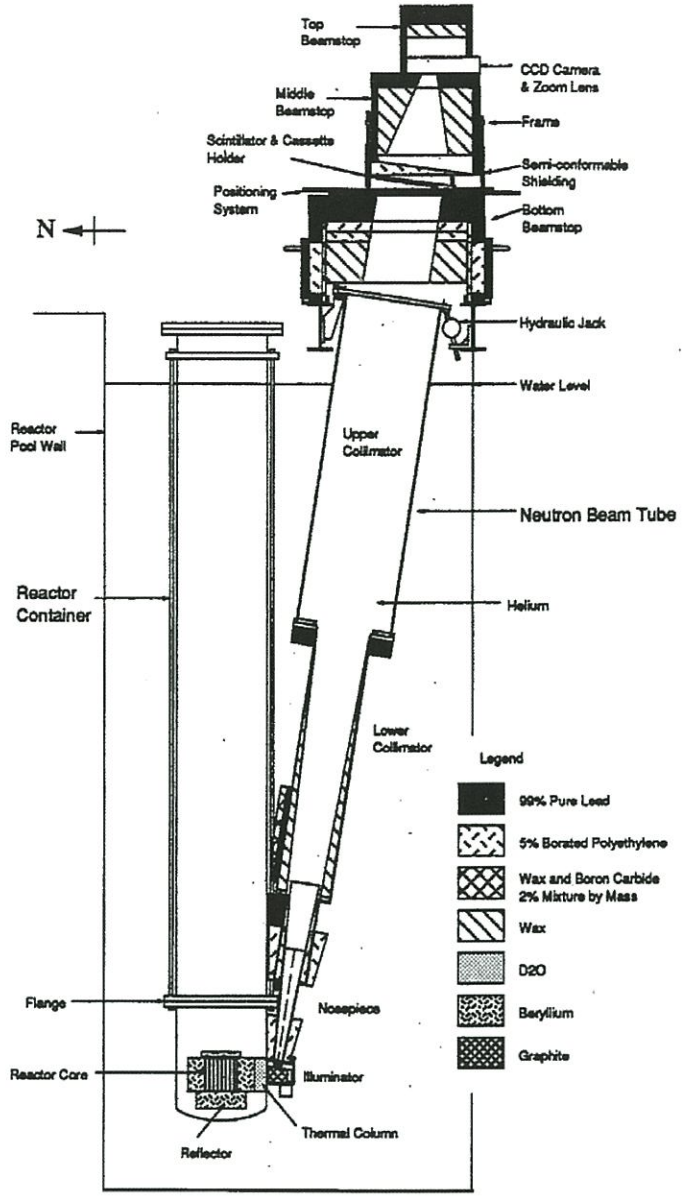


Figure 2: Side View of RMCC Neutron Imaging System.

vertically in the reactor pool away from the core. To initiate imaging, the NBT is moved towards the reactor core by a hydraulic jack until the bottom of the NBT contacts the reactor container and forms an 8.5° angle from vertical. The bottom of the NBT is called the illuminator and is made from a graphite block. When the NBT is coupled to the reactor container, neutrons travel through the beryllium reflector and the heavy water thermal column to the graphite block. The graphite block redirects the neutron beam upwards through the divergent beam tube. The beam tube and peripheral equipment required for neutron imaging are shown in Figure 2.

2. Applications

Three specific applications relevant to the CAF for NAA, DNC and neutron imaging will be briefly examined.

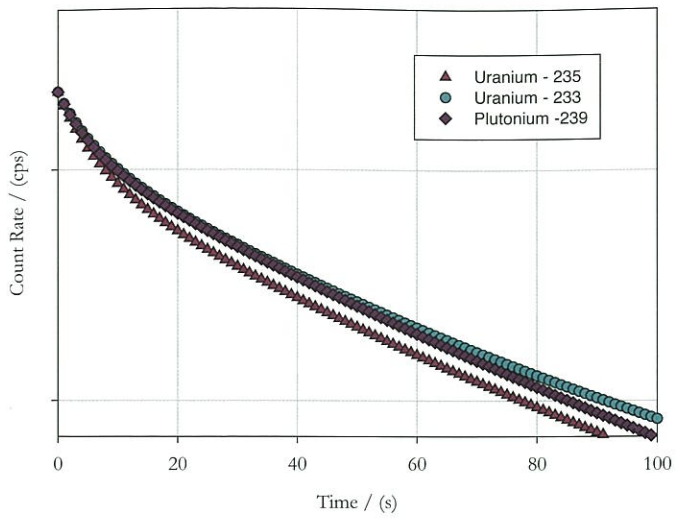


Figure 3: Time Dependant Delayed Neutron Counts for SNMs U-233, U-235 and Pu-239 Normalized to Equal t=0 Counts.

2.1 Neutron Activation Analysis (NAA)

NAA is a nuclear based technique used to identify and determine the concentrations of elements in material samples. The samples under inspection are bombarded with neutrons,producing radioisotopes. The gamma emissions from the isotopes are characteristic of elementsand the recorded spectra can be analyzedusing well-known decay paths.

As part of its role as an environmental custodian, the CAF is committed to the assessment, control and mitigation of contaminants from SARs. Actions include the assessment of soil contamination, particularly by copper, lead and antimony. The ability of NAA to accurately determine the concentrations of antimony in soil samples was compared to other analytical techniques including nitric acid, *in situ* HF microwave digestions and nitrate ashing. It was concluded that only NAA is capable of providing data which reflect 'true' concentrations[3]. Since antimony represents a significant mass fraction of many munitions and since its toxicity is considered comparable with that of arsenic, the provision of reproducible and accurate laboratory data with respect to antimony in soil is essential. Due to its ability to accurately and easily measure total antimony content in soil, the CAF uses NAA to measure soil samples from its SARs.

2.2 Delayed Neutron Counting (DNC)

A prototype DNC system has been developed within the SLOWPOKE-2 Facility to enhance nuclear forensic instrumentation available to the CAF[4]. An array of ^{3}He detectors record the temporal behaviour of delayed neutrons produced after the irradiation of special nuclear material (^{233}U, ^{235}U and ^{239}Pu) in one of the

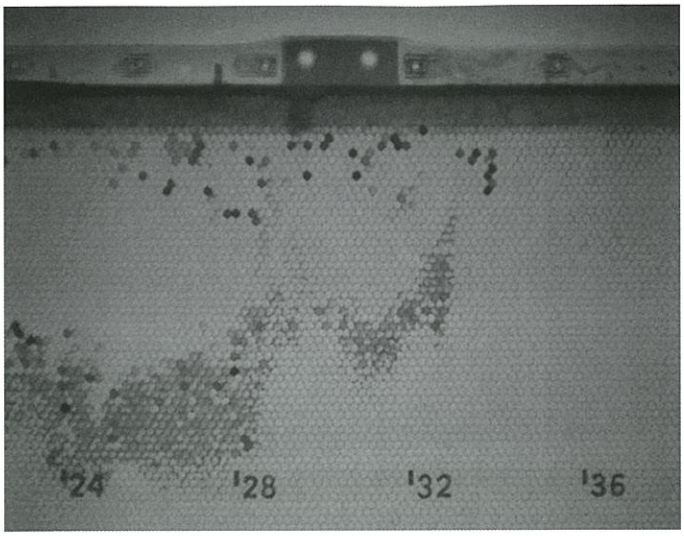


Figure 4: Water Ingress in CF-188 Rudder.

irradiation sites of the SLOWPOKE-2 reactor. The DNC allows for the rapid and non-destructive analysis of fissile mixtures. Figure 3 provides a theoretical difference in delayed neutron temporal behavior for various SNMs initialized to the same count rate.

The DNC system has recently been upgraded to simultaneously record delayed neutrons (He-3 detectors) and delayed gammas from via the inclusion of a high purity germanium detector.

Delayed measurements from this system are compared to MCNP6 simulations in collaboration with the Monte Carlo Codes group at Los Alamos National Laboratory[5].

2.3 Neutron Imaging

The honeycomb composite flight control surfaces (FCS) on the CF-188 aircraft are susceptible to water ingress. Water enters these components and can cause structural degradation to the interior honeycomb structure. The degradation can become so severe that numerous ruddershave departed the aircraft during flight. The CAF conducted an evaluation of various non-destructive evaluation (NDE) techniques capable of locating water within honeycomb composites. Several NDE techniques proved effective at locating the water, but neutron imaging was determined to be the most sensitive[6]. A neutron radiograph of water inside the honeycomb core of a CF-188 rudder is shown in Figure 4.

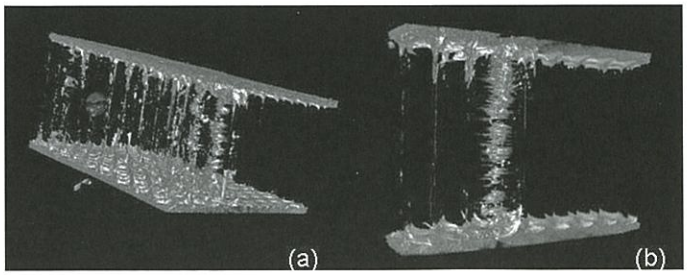


Figure 5: Water Ingress in Honeycomb Core; Full View(a), Section View (b).

Neutron imaging was used as the primary NDE technique in the development of an effective and non-invasive water removal technique for CF-188 flight surfaces. The successful drying method utilizes vacuum pressure and heat to allow water to be removed from the FCS[7]. This process is now performed at CAF fighter bases and has been instrumental in the reintroduction of numerous rudders previously compromised by water ingress. However, not all rudders can be returned to service following the drying procedure. The original designer of the rudders, Northrup Grumman, has developed water ingress limits which restrict the location and degree of water exposure, due to fears of structural degradation[8][9].

In order to characterize degradation in honeycomb composites and assist in the quantification of degradation, a neutron tomography system was designed and built at RMCC[10]. The tomography system is capable ofdetermining the exact location of water ingress inside honeycomb composites and to identify which structural adhesive bonds potentiallyare degraded. Figure 5 is a neutron tomographic reconstruction of wateringress in a section of the honeycomb composite core of a CF188 rudder (full and side view).

Conclusions

The SLOWPOKE-2 nuclear research reactor is a powerful and important scientific resource for the CAF. Nuclear capabilities provided by the reactor are used to measure and evaluate a wide range of issues significant to the CAF. NAA is effectively used to determine antimony contamination in SMRs, in coordination with the CAF environmental stewardship program. The design of a DNC system at RMCC provides the CAF with enhanced nuclear forensics capabilities, which can discriminate various SNMs. Lastly the SLOWPOKE-2 Facility has been enhancedto provide neutron imaging, which has proven very effective for the non-destructive evaluation and subsequent repair of CF-188 honeycomb composites. RMCC is committed to continuing to improve and modify the current nuclear capabilities provided by the SLOWPOKE-2 nuclear reactor as well as investigating new opportunities to increase the nuclear capabilities available to the CAF.

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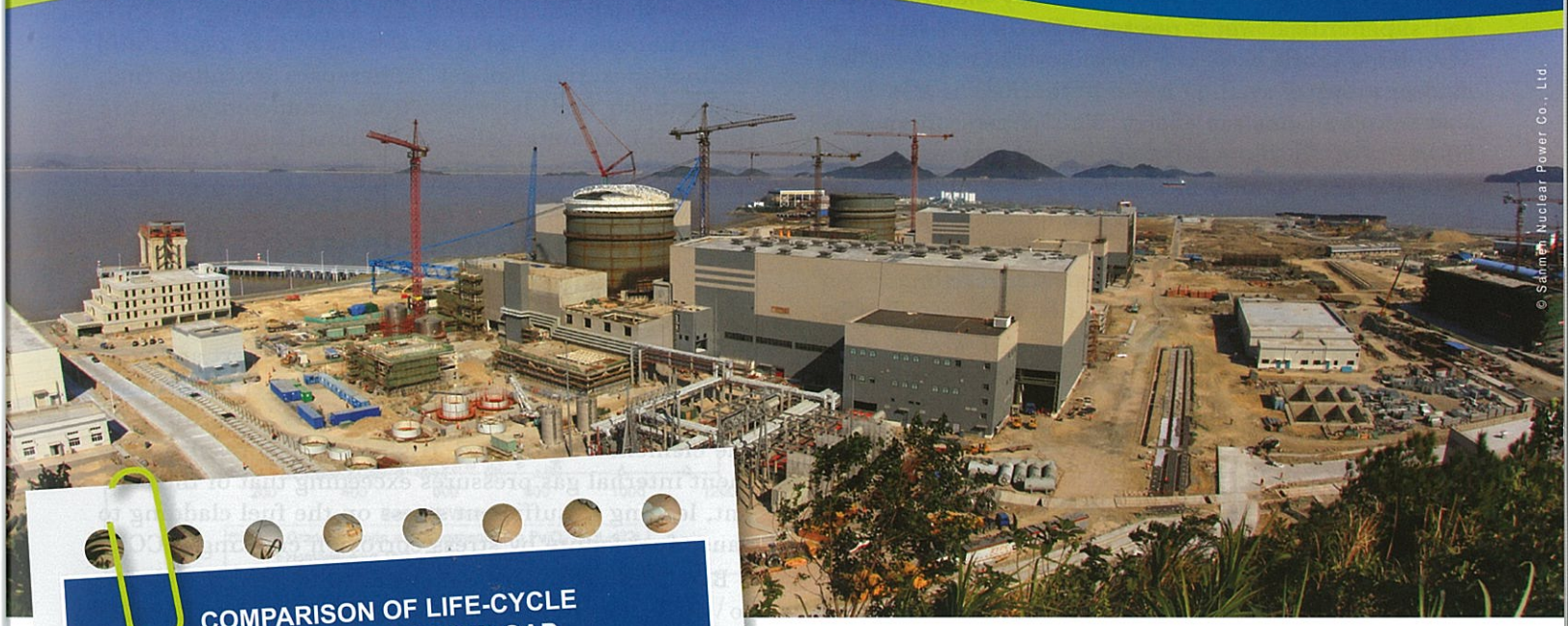
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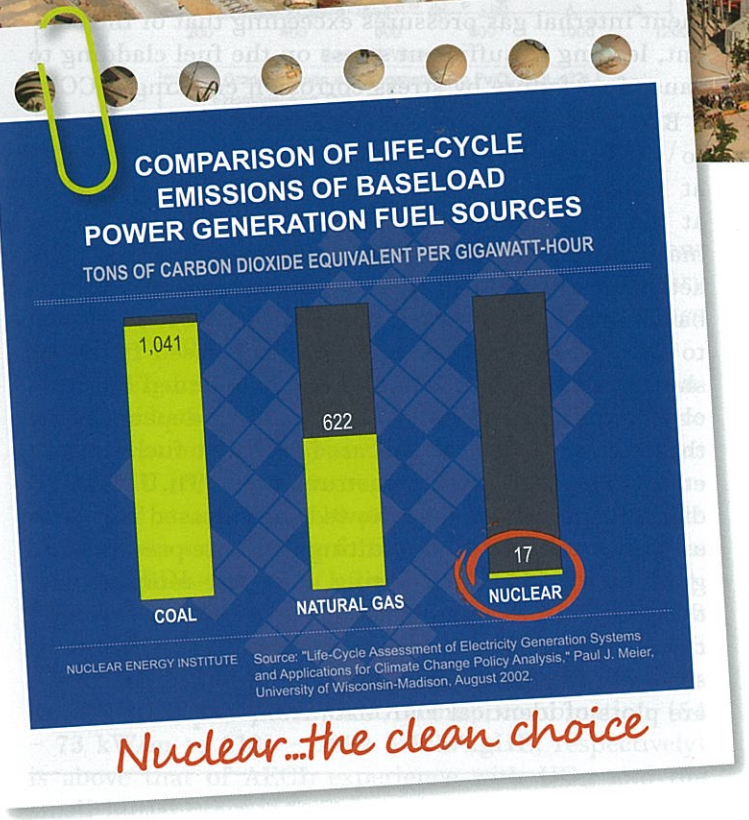
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Thoria Irradiation and Post-Irradiation Examination Experience at AECL

by S.J. LIVINGSTONE[1] and M.R. FLOYD[1]

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ABSTRACT

Thorium is envisioned to play a significant role in future global nuclear fuel cycles. Thoria (ThO_2) based fuels are under consideration for deployment in the Canadian- designed pressurized heavy water reactor and super-critical water reactor. AECL's experience in developing thoria fuels is a key enabler to the Canadian nuclear industry availing itself of thorium as a sustainable source of nuclear energy. This paper summarizes 50 years of AECL experience with thoria irradiation tests and performance assessments from ~1962 to the present. The paper reviews irradiation tests conducted in two experimental reactors, and the Nuclear Power Demonstration pressurized heavy water reactor.

Introduction

Various thoria-based fuels have been studied by AECL including natural thoria (ThO_2), (Th,U)O2, and (Th,Pu)O2, with ^{235}U (in HEU) or Pu content ranging from 1-4 wt.% [1]. Fuel burnups up to 1130 MWh/kgHE (47 GWd/tHE) have been achieved, with linear powers up to 73 kW/m. Tests that studied defected fuel, power ramp behaviour, high burnups, different pellet fabrication methodologies, and pellet microstructure investigations are summarized. Key findings and lessons learned from irradiation tests and post-irradiation examinations are described.

Experience is contrasted with that of CANDU UO_2 fuel. Specific fuel performance attributes are discussed, including fission gas release, pellet microstructure behaviour, sheath strain/corrosion/hydriding, and defected fuel performance. Irradiation tests that are in progress (targeting burnups up to 1500 MWh/kgHE (63 GWd/tHE)) are described, as well as envisioned initiatives that will provide additional thoria fuel science and technology to Canada and the world.

This paper focuses on AECL experience with ThO_2-based fuel irradiations in the NRU (National Research Universal), NRX (National Research eXperimental) and NPD (Nuclear Power Demonstration) reactors. Physics experiments in the ZED-2 (Zero Energy Deuterium) critical facility using a variety of thoria based fuels (including 233U experiments) are not discussed [2].

AECL also has experience with irradiating thoria fuels in the WR-1 organic-cooled reactor (high temperature, low pressure coolant [3]), LWR-type thoria fuel rods in NRX [4], and CANDU geometry fuels in the NRU moderator (low temperature and low pressure coolant) [5].

Irradiations of Th-based alternate fuel fabrication technologies (i.e., sol-gel, spherepac, extruded fuel, and annular fuel) have also been conducted by AECL; only solid ceramic pellet ThO_2-based fuels fabricated from powders are described in this paper.

1. Fission Gas Release (FGR)

Fission gas release (FGR) is a key parameter of fuel performance, particularly at high power (i.e., high temperature) and extended burnup [6]. Inert and volatile fission gases are produced in the fuel matrix as a result of fission, and a fraction of this gas diffuses to the element free volume. High FGR may result in element internal gas pressures exceeding that of the coolant, leading to sufficient stress on the fuel cladding to cause fuel failure by stress corrosion cracking (SCC).

Based on its superior thermal conductivity (relative to UO_2), thoria-based fuels are expected to operate at lower temperatures compared to UO_2 operating at the same power. Thoria is also a more refractory material than UO_2; since FGR is primarily a thermally activated diffusion process, it is expected that thoria-based fuels should experience reduced FGR compared to UO_2. AECL experience with thoria-based fuels has shown their FGR to be reduced, or bounded by those observed from similarly operated UO_2, depending on the microstructure of the as- fabricated fuel. Smith et al. [7] performed an instrumented (Th,U)O2 irradiation experiment that showed thoria-based fuel with as-fabricated granules (resulting from pre-pressing and granulating stages) operating at higher temperatures than fuel with a homogeneous, dense microstructure; this behaviour was observed in several experiments as shown in Figure 1 and Figure 2. Figure 1 and Figure 2 are plots of identical FGR data from UO_2 [6] and vari-

1 Atomic Energy of Canada Limited, Chalk River, Ontario, Canada.

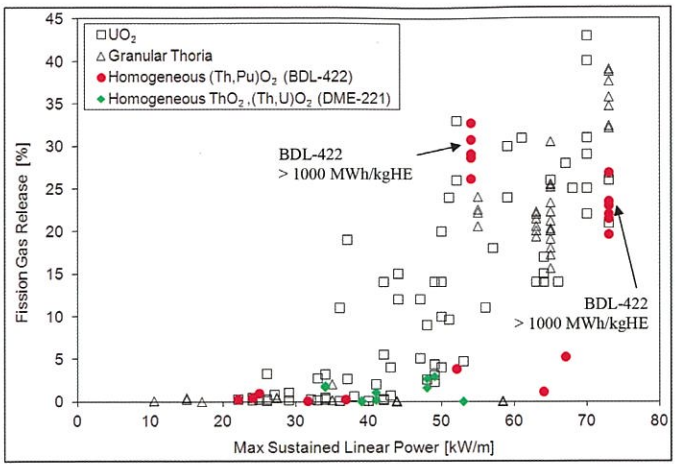


Figure 1: FGR [%] as a Function of Maximum Sustained Linear Power [kW/m]. The BDL-422 (Th,Pu)O_2 with FGR > 15% have Burnups > 1000 MWh/kgHE (42 GWd/tHE).

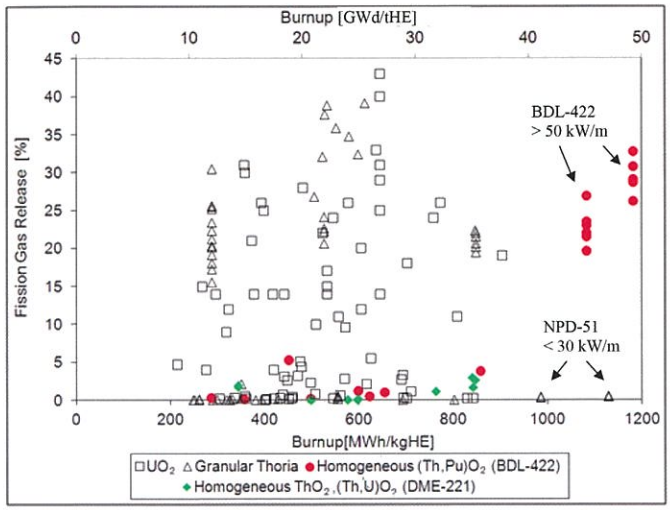


Figure 2: FGR [%] as a Function of Burnup [MWh/kgHE (bottom) and GWd/tHE (top)].

ous thoria- based fuels plotted against their element power (Figure 1) and burnup (Figure 2) (primary dependence on power, with a secondary dependence on high (> 900 MWh/kgHE, 38 GWd/tHE) burnup).

From Figure 1 and Figure 2, it is apparent that granular thoria-based fuels have similar FGR characteristics to conventional UO_2 based fuels, while irradiations (DME-221 [8]) with homogeneous pellet microstructures and standard (5- 10 µm) as-fabricated grain size have shown superior performance. In the case of non-granular BDL-422 fuel (1.5 wt% Pu in (Th,Pu)O2 [9]), the FGR was low (< 5 %) below 1000 MWh/kgHE (42 GWd/tHE), and high (> 23 %) above 1000 MWh/kgHE (42 GWd/tHE) [10]. For the high burnup elements in BDL-422, the power and burnup combination (54 – 73 kW/m to 1181 – 1082 MWh/kgHE, respectively) is above that of AECL experience with UO_2, and the small initial grain size (3 – 4 µm versus 5 – 10 µm in production CANDU fuel) may also have contributed to the high FGR [11]. For fuels operating at < 30 kW/m, it appears that FGR remains low regardless of fuel composition or microstructure (e.g., granular NPD-51 thoria fuel was irradiated in the Nuclear Power Demonstration reactor at < 30 kW/m up to 1130 MWh/kgHE (47 GWd/tHE) with only 0.5 % FGR).

2. Pellet Microstructure Behaviour

Thoria fuels with homogeneous microstructure generally exhibit less grain growth than UO_2 fuel. For example, BDL-422 bundles ADC, ADE and ADF that contained (Th,Pu)O2 pellets were irradiated at powers of 52-67 kW/m to burnups of 451 – 856 MWh/kgHE (19 – 36 GWd/tHE); a grain growth factor of ~ 3 was observed [9]. In comparison, at lower power (47 – 53 kW/m) and a burnup of 450 – 750 MWh/kgU (19 – 31 GWd/tHE), UO_2 is expected to have a grain growth factor of the order 1.5 to 3.5 [6]; this demonstrated that higher power and higher burnup Th- based fuel had grain growth comparable to lower power and lower burnup UO_2 fuel. Grain growth factor is the ratio of the observed pellet-centre grain size to that at the pellet periphery, assumed to represent the as-fabricated pellet-centre grain size.

No thoria fuel irradiated by AECL has exhibited columnar grain growth, despite several having powers exceeding 65 kW/m; UO_2 typically exhibits columnar grain growth at this power [6].

BDL-417 and BDL-422 operated at ~ 73 kW/m at the beginning of life (BOL) and only exhibited equiaxed grain growth [6] [10]. This is consistent with reports that suggest significantly higher temperatures are required for columnar grain growth to occur in thoria-based fuels (relative to UO_2) [12] [13]; columnar grain growth is affected by various material properties, for example the fuel vapour pressure (lower in Th than UO_2), and the temperature to melting point ratio (thoria has a higher melting point and improved thermal conductivity).

Apparently, conditions for columnar grain growth in thoria are not achieved at powers up to 73 kW/m

3. Sheath Strain, Corrosion, Hydriding Behaviour and CANLUB Retention

Sheath residual strains (mid-pellet and pellet-pellet interface) of thoria fuels with homogeneous pellet microstructures are bounded by ±0.6 %, despite high burnups and powers, varying pellet geometries, and different fuel compositions. The residual sheath strains of the thoria fuels are comparable to UO_2

sheath residual strains [6]. Sheath hydriding/deuteriding and oxidation (internal and external) behaviour show no significant difference from UO_2 fuels. CANLUB retention in thoria-based fuel is consistent with that observed in UO_2 fuels.

4. Performance of Defected Thoria-Based Fuels

A fuel defect refers to a breach in the fuel sheath that allows heat transport system (HTS) coolant to enter the element, and fission products (and likely fuel) to escape the element. This section describes defect root causes, post-defect degradation, and fission product release from defected Zircaloy sheathed thoria-based fuel.

4.1 Defect Root Causes

To date, AECL experience has shown no defect root causes that are unique to thoria-based fuel. Defect root causes in thoria-based fuel experienced at AECL include: SCC (stress-corrosion cracking; from internal gas overpressure or power ramping), primary hydriding, longitudinal sheath ridging (from low density fuel pellets), and incomplete endcap-to-sheath closure welds. All of these defect mechanisms occur in standard CANDU UO_2 fuel [14], and are related to manufacturing or operational issues.

Thoria-based fuels irradiated by AECL have exhibited similar power ramp SCC defect thresholds to those developed empirically for UO_2 fuels. The differences in ThO_2 and UO_2 material properties (e.g., thermal conductivity and melting point) do not appear to have a major net effect on power ramp SCC defect thresholds, and may be offsetting in nature. Further investigation is required to determine the impact of differing ThO_2 and UO_2 material properties on power ramp performance.

4.2 Post-Defect Degradation

Both thoria and UO_2 fuels appear to exhibit similar secondary sheath degradation (sheath hydriding resulting from coolant ingress via primary defects). AECL experience with thoria- based and UO_2 fuels follow UO_2 secondary hydriding thresholds developed by Locke [15]. No unique post-defect degradation mechanism has been observed in thoria-based fuel; in some aspects, defected thoria fuel appears to experience reduced degradation relative to UO_2, as described below.

When UO_2 fuels operate in a defected state, the pellets experience oxidation (O/M ratio > 2.00). As a result, grain boundary oxidation increases fuel loss (to the HTS; i.e., erosion) and thermal conductivity is

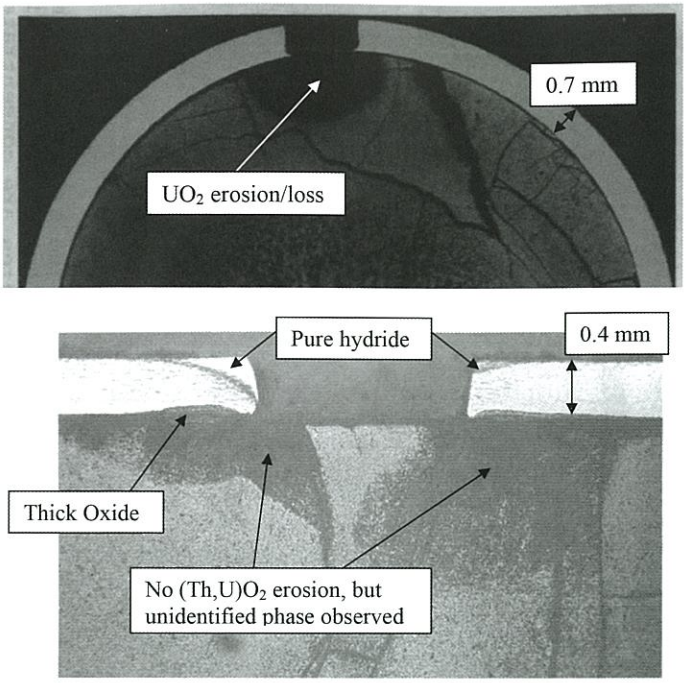


Figure 3: Fuel Erosion from UO_2 (top) and (Th,U)O2 (bottom) under Similar Conditions

degraded leading to higher fuel temperatures. Higher fuel temperatures cause increased grain growth and enhanced fission gas release to the HTS [16]. Since ThO_2 is chemically stable, fuel oxidation does not occur and, therefore, fuel loss remains low and thermal performance is not expected to change. Further investigations are required to determine if grain growth (and fuel operating temperature) in thoria-based fuels are affected by fuel defects, and how increasing the Pu or U content in ThO_2 might impact defect performance.

Thoria fuels irradiated by AECL have consistently exhibited reduced pellet erosion and fission product release (Section 4.3) as compared to UO_2 fuel. For example, an axial split in DME-166 fuel (SCC failure resulting from a power-ramp) resulted in minimal erosion of the (Th,U)O2 pellet (1.66 wt% UO_2 with 93 wt% ^{235}U in total U) under the large axial sheath split.

Furthermore, during the parallel FDO-680 (Th,U)O2 and FDO-681 UO_2 experiments (discussed in Section 4.3), negligible (Th,U)O2 loss was observed, while significant UO_2 fuel loss occurred (Figure 3). Figure 3 shows typical erosion from the UO_2 pellet, but the (Th,U)O2 pellet under the defect site shows no evidence of erosion; it is not clear if the unidentified phase observed in the (Th,U)O2 micrograph is real or an artifact of the metallographic preparation process.

4.3 Fission-Product Release

Fission product release from thoria-based fuel has generally been less than that from UO_2 fuel operating under similar conditions. Early (pre-1970) AECL

$$\frac{R^{eq}}{B} = \frac{3\nu}{(\nu+\lambda)}\sqrt{\frac{X^2 D'(P)}{\lambda}}H + c \xrightarrow{Single\ defect\ (X=1),\ ^{133}Xe\ (\nu \gg \lambda, c \ll defect\ release, H \approx 1)} \approx 3\sqrt{\frac{D'(P)}{\lambda}} \quad (1)$$

$$\frac{R^{eq}}{B} = \frac{M_c}{B\lambda}\left(\left(\lambda + \frac{\beta_p IX_{eff}}{M_c} + \frac{\epsilon}{M_c}\right)C_{eq}\right) \xrightarrow{^{133}Xe\ (IX_{eff}=0),\ no\ leakage} \approx \frac{M_c C_{eq}}{(B = F_f y_c L P)} \quad (2)$$

Where:

R^{eq}/B	=	Equilibrium release rate to birth ratio
ν [s^{-1}]	=	Escape rate coefficient
λ [s^{-1}]	=	Decay constant
X	=	Number of defects
$D'(P)$ [s^{-1}]	=	Emprical diffusion coefficient
H	=	Pre-cursor correction factor
M_c [kg]	=	Coolant mass
$\beta_p IX_{eff}$ and ϵ [$kg.s^{-1}$]	=	Purification and leakage terms
C_{eq} [$Bq.kg^{-1}$]	=	Activity concentration
F_f [$fission.s^{-1}.kW^{-1}$]	=	Fission rate per kilowatt
y_c [%]	=	Cumulative yield
L [m]	=	Defected element length
c	=	Uranium contamination contribution
P [$kW.m^{-1}$]	=	Defected element power

experience with defected thoria fuels did not include the collection of detailed fission product data; notwithstanding, anecdotal evidence existed at that time that radioiodine and fission gas release were lower in thoria than similarly operated UO_2 fuels that experienced failure.

In the mid-1970's, AECL conducted a parallel defect experiment where a defected UO_2 element (FDO-681 element RPL with 4.5 wt% ^{235}U in total U [17]) and defected (Th,U)O2 element (FDO-680 element HKL with 4 wt% UO_2 in ThO_2 (93 wt% ^{235}U in total U)) were irradiated separately in the X-2 loop of the NRX reactor. While a complete analysis of this experiment is outside the scope of this paper, a simple analysis using 133Xe release is described below.

Due to the inert nature of 133Xe and its 5.2 day half-life, its release from defected fuel can be approximated as independent of defect size and uranium contamination. This approximation is shown in Equation (1) as a simple model for R/B (release over birth rate) for steady-state release [17], [18] from a defect. Equation (2) is the measured value, modified to include the element length (L) as FDO-680/1 were short elements.

Figure 4 shows the results of Equation (2) applied to CANDU reactor data [19] and NRX data from a suite of UO_2 defect experiments [17] compared with FDO-680 and FDO-681 data. The FDO-681 UO_2 and FDO-680 (Th,U)O2 data are from short element irradiations (~ 170 mm stack length versus ~ 480 mm in the other experiments and reactor data); other experiment and reactor parameters are similar. This preliminary analysis indicates significantly reduced (10 –100 times) release of 133Xe from defected (Th,U)O2

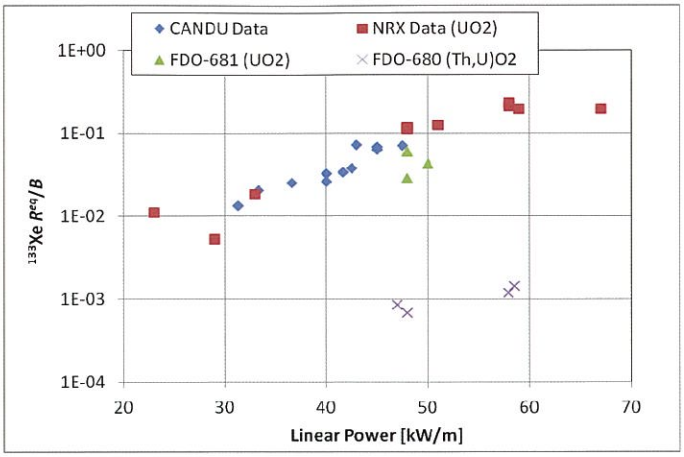


Figure 4: ^{133}Xe Release Fraction (R^{eq}/B) as a Function of Power. 'CANDU Data' is Commercial Reactor Data, 'NRX Data' is UO_2 Defects in the NRX X-2 Loop, and 'FDO- 680/FDO-681' were Short Elements Irradiated in the NRX X-2 Loop.

versus UO_2 in the 50 – 60 kW/m power range. Further investigations are required to confirm this finding, and to further explore fission- product release behaviour from defected thoria-based fuels.

5. Current and Future Irradiations

The DME-221 experiment includes the irradiation of eighteen fuel elements in a demountable configuration [8], [10]. Six of the elements contain natural thoria, while the other twelve contain (Th,U)O2. Six of the (Th,U)O2 elements contain 1.0 wt.% ^{235}U (in total heavy elements), while the remaining six contain 1.5 wt.% ^{235}U. The elements were irradiated to maximum powers of 36-55 kW/m. To date, PIE has been completed on twelve DME-221 elements that achieved burnups of 361-929 MWh/kgHE (15-39 GWd/tHE). Six DME-221 elements are planned to continue their irradiation to burnups of 1000-1500 MWh/kgHE (42-63 GWd/tHE).

The "Thoria Roadmap Project" is a major development in AECL's recent initiatives to ensure sustainable nuclear energy for future generations. Launched in 2012, this project seeks to identify knowledge gaps in science and technology (S&T) areas associated with thoria-based fuels and fuel cycles. This

is being accomplished by measuring fundamental requirements against current understanding in various S&T areas. The outcome will be a "roadmap" to address gaps in current understanding, which will better position Canadian industry to implement thoria-based fuels in commercial nuclear power reactors. Irradiation Testing is one of the S&T areas being investigated. Preliminary investigations indicate that additional irradiation testing is required to understand the effect of pellet grain size variations and Pu homogeneity in (Th, Pu)O2 fuels irradiated to high burnup. These irradiation tests are presently in the early stages of planning.

Conclusions

AECL has 50 years of experience with thoria irradiation tests and performance assessments (ThO_2, (Th,U)O2, and (Th,Pu)O2) with burnups up to 1130 MWh/kgHE (47 GWd/tHE) and linear heat ratings up to 73 kW/m. Experience includes defected fuel experiments, power ramp tests, instrumented fuel, various pellet fabrication methodologies, and pellet microstructure variations.

In general, AECL thoria-based fuel performance is bounded by that of UO_2 fuel. Thoria-based fuels having high-density pellets with homogeneous microstructures exhibit superior fission-gas release behaviour to UO_2. Defected thoria fuels exhibit lower fission-product release and less fuel degradation; one experiment showed 10-100 times reduced release of 133Xe from defected (Th,U)O_2 versus UO_2 in the 50-60 kW/m power range.

Work is on-going to identify and address thoria fuel S&T gaps. This includes extending the burnup of DME-221 ThO_2 and (Th,U)O2 fuels to burnups of 1500 MWh/kgHE (63 GWd/tHE), and to investigate the effect of pellet grain size and Pu homogeneity on (Th,Pu)O2 fuel performance at high burnup. Other initiatives are expected to be undertaken as additional S&T gaps are identified by AECL's Thoria Roadmap Project.

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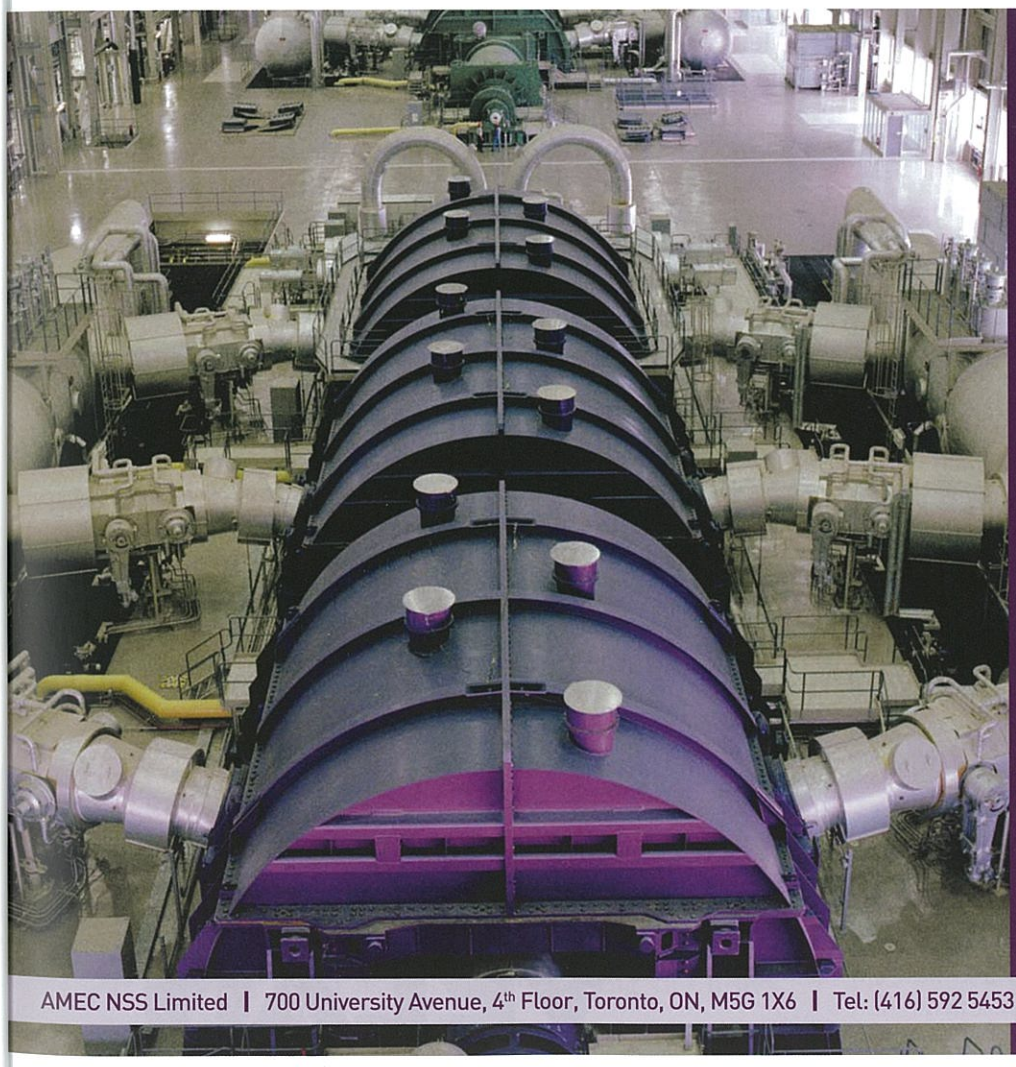
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End of a Major Program

"Licence to Abandon" Marks End of the Heavy Water Program

by FRED BOYD

When the Canadian Nuclear Safety Commission issued the strangely worded "Licence to Abandon" for the Bruce Heavy Water Plant on February 3, 2014, it marked the end of a program that at one time was considered to be the potential "Achilles Heel" of the Canadian nuclear power program. (A "Licence to Abandon" means that after a month there will be no CNSC restriction to the use of the land where the plant had been.)

The story goes back to the 1960s.

Canada's first nuclear power plant, the 20 MWe NPD, started up in 1962. It soon showed that the heavy water moderated, natural uranium, pressure tube design worked and could be the basis for commercial scale plants. To go that route would require a reliable and economic supply of heavy water (D_2O).

In 1963 the federal government, through Atomic Energy of Canada Limited, issued a contract to a company called Deuterium of Canada Limited (DCL) to build a heavy water plant in Glace Bay, Nova Scotia, capable of producing 200 tons of heavy water per year. The process to be used was called the Girdler-Sulphide system which involved a dual temperature hydrogen sulphide (H_2S – water) exchange process operating at high temperatures and pressures.

When Ontario Hydro decided in 1964 to build two 500 MWe CANDU type units at Pickering, Ontario, AECL issued in 1965 a further contract for a heavy water plant to be built by Canadian General Electric, also in Nova Scotia at Port Tupper.

Ontario Hydro continued to expand its plans and in 1968 decided to build what is now called Bruce A. This would require even more heavy water and the government decided to build a 400 tons per year plant (later increased to 800) at the Bruce site.

On top of these plans by Ontario Hydro, plants were planned for New Brunswick, Quebec and Argentina. Very optimistic predictions were made for the future of nuclear power in Canada. Electricity demand had been doubling every ten years for several decades. An interdepartmental study on the Canadian Nuclear Program conducted in 1973 predicted that there could be 100,000 MWe of nuclear generation by the year 2,000.

The same study concluded that a one-year delay in the start-up of a completed nuclear plant would cost six times as much as the cost of having the heavy water a year early.

However, as events developed, Darlington was the last nuclear power plant built in Canada. Even with overseas sales the demand for heavy water never reached that predicted.

On the licensing side, the Atomic Energy Control Act stipulated deuterium as a material to be controlled. The Atomic Energy Control Board (predecessor of the CNSC) chose originally to only licence the product D_2O, leaving the safety issues to the provinces.

However, in November 1968, during a hot test of the Glace Bay plant, a major leak developed and about 10,000 pounds of H_2S was released. H_2S is very toxic and the release could have been very deadly if it had been directed inland rather than out to sea.

This caused the AECB to quickly change its policy. It decided to rule on the safety of the Bruce plant. Particular concern was focussed on the near-by Inverhuron Provincial Park at the southern edge of the Bruce site. Combined demand by the AECB and the public led Ontario Hydro to buy land 25 km north of the Bruce site and loaning it to the Ontario Ministry of Natural Resources which established a new park.

Although four units had been planned for the Bruce HWP only two were completed. They were shutdown in 1998. Ontario Power Generation, which inherited the plants from Ontario Hydro, began decommissioning in 2004. In 2007 this was expanded and CNSC authorized complete demolition of the plant to make the area available for other uses.



Old view of Bruce site showing heavy water plant with Bruce A in foreground

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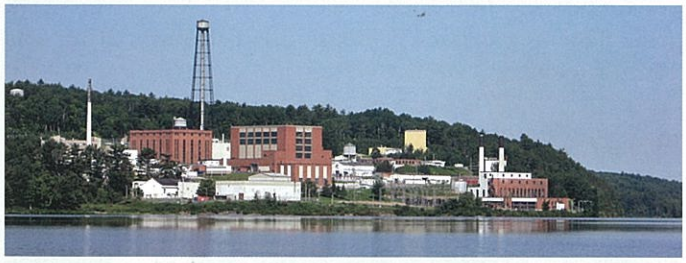
(Compiled by Fred Boyd from open sources)

Restructuring of AECL Moves Ahead

On March 7, 2014 the Minister of Natural Resources, Joe Oliver, announced the next step in the restructuring of Atomic Energy of Canada Limited (AECL): the launch of the process to qualify potential suppliers to manage and operate AECL's Nuclear Laboratories, in the context of a Government-owned Contractor-operated (GoCo) model.

A *Request for Response Evaluation* (RFRE) has been posted on the Government Electronic Tendering Service inviting interested suppliers to demonstrate that they have the experience, expertise and financial capacity necessary to manage a nuclear organization as complex as AECL's Nuclear Laboratories. Should they qualify, suppliers would then be able to engage in detailed consultations with the Government on this opportunity and, ultimately, to submit bids in response to a Request for Proposal.

The Minister emphasized that the Canadian Nuclear Safety Commission, Canada's independent nuclear regulator, will continue to regulate all parts of Canada's nuclear industry, including the Nuclear Laboratories during and after the restructuring process.



View of Chalk River Laboratories from Ottawa River.

New Chairs Appointed to OPG and Hydro One

On March 7, 2014 the Ontario Minister of Energy, Bob Chiarelli, announced the appointment of new Chairs of the Board of Ontario Power Generation and Hydro One.

Bernard Lord is appointed Chair of the Board of Directors of the Ontario Power Generation (OPG) and **Sandra Pupatello** as Chair of the Board of Directors of Hydro One effective April 1, 2014.

Mr. Lord is a former Premier of New Brunswick and current President and CEO of the Canadian Wireless Telecommunication Association. As Premier, Mr. Lord was engaged in important issues relating to the electricity sector. He will replace Jake Epp, who has been OPG Chair for the past six years.

A former Ontario cabinet minister, Ms. Pupatello is CEO of Windsor Essex Economic Development Corp., and Director, Business Development and Global Markets at PricewaterhouseCoopers.

Mr. Lord and Ms. Pupatello and will provide advice and guidance to help deliver clean, reliable and affordable energy to Ontario's families and businesses. They will lead efforts to find efficiencies and address human resource issues, executive compensation as well as potential pension reform.

The Minister added that government will work with Mr. Lord and Ms.Pupatello in the coming weeks as the membership of the Boards of Directors of Hydro One and OPG are renewed.

CNSC signs MOU with Fisheries and Oceans Canada

On February 28, 2014, the Canadian Nuclear Safety Commission (CNSC) announced that it had signed a Memorandum of Understanding (MOU) with Fisheries and Oceans Canada (DFO) for cooperation and administration of the Fisheries Act.

Under the MOU, DFO will rely on the CNSC to take on responsibilities for the assessment and monitoring of environmental impacts on fish, including species listed in the Species at Risk Act (SARA) and to make recommendations to DFO related to authorizations under the Fisheries Act.

The CNSC has always reviewed impacts to the environment, including impacts to fish and fish habitat, under the Nuclear Safety and Control Act. Recent projects include the Darlington new nuclear power plant project, the Pickering Nuclear Generating Station refurbishment and the Key Lake uranium mine licence amendment. Under the MOU, the CNSC will ensure its reviews take into consideration the requirements of the revised Fisheries Act.

The Minister of Fisheries and Oceans remains

accountable for decisions under the habitat provisions of the Fisheries Act and for protecting aquatic species listed under the SARA.

The MOU is available on the CNSC website: *http://www.nuclearsafety.gc.ca/eng/pdfs/MoU-Agreements/2014-02-27-mou-cnsc-fisheries-oceans-eng.pdf*

Promation Nuclear Completes QM Audits

Promation Nuclear recently reported that it had successfully completed several Quality Management Program and compliance audits over the past few months resulting in continued compliance to:

- CSA Z299.1/.2/.3
- ISO 9001:2008
- TSSA Certifications in Accordance with CSA Standard N285 include:
  - Construction of Class 1, 2, 3 & 4 Vessels, Tubular Products, and Piping Systems and Subassemblies
  - Class 1, 2, & 3 Shop Assembly as a Material Organization supplying Ferrous and Nonferrous Material
  - Fabrication of Class 1, 2 & 3 Welded and Non-Welded Category A, B, D, E & H type Fittings
  - Fabrication of Class 1, 2, 3, & 4 Welded and Non-welded Supports
  - Field Repairs, Modifications or Replacements of Class 1, 1C, 2, 2C, 3, 3C and fittings at CANDU Nuclear Power Plants
- CSA W47.1/W59.1
- CSA W47.1/W59.2

Promation Nuclear, a member of the Organization for Candu Indusrty (OCI), is a leading designer and manufacturer of high-quality tooling, automation, and robotic systems. Its engineering and advanced technologies are designed to support plant life management, extend plant design life, reduce maintenance costs and develop cost-effective solutions to existing challenges. The company has developed a wide range of solutions including specialty equipment and automated tooling for reactor refurbishment, fuel handling systems and large scale mock-ups.

For more information email: vicki@promation.com

Cameco Sells Stake in Bruce Power

Saskatoon-based uranium producer Cameco has sold its stake in Ontario's Bruce Power plant for $450 million.

The buyer of the 31.6 per cent stake is BPC Generation Infrastructure Trust (Borealis), which is owned by Ontario Municipal Employees Retirement System. The takeover was effective Dec. 31, 2013.

OMERS, one of Ontario's biggest pension funds, becomes the majority owner of Bruce Power. It first bought into the Bruce Power system in 2003, when British Energy sold its 31.2 per cent stake. TransCanada also owns a stake in the limited partnership.

Cameco CEO Tim Gitzel said his company plans to "reinvest in our core uranium business where we see strong potential for growth."

Point Lepreau Turbine Rotors Finally On Site

Transportation of Turbine Rotors Completed Safely

On January 19 and February 2, 2014, two 130-tonne rotors made six-hour journeys on a specialized tractor trailer from the Port at West Saint John, to the Point Lepreau Generating Station. The moves were completed in a safe and event-free manner with minimized impacts to the public. The rotors were stored outside at PLGS until the end of February, when both rotors were moved inside the Station.

Siemens, the manufacturer, has completed detailed inspections of both rotors and confirmed that no damage occurred during shipping.

The new rotors will replace two of the three current rotors in service at the Station which were deemed acceptable for shorter term use after they were damaged in transit in 2008. This replacement will occur during a future planned maintenance outage over the next two to three years.

As of the first week of March the Station continued to operate at 100 per cent reactor power, putting approximately 660 megawatts on the New Brunswick grid. The net capacity factor for February 2014 was 100 per cent.

New Head of Candu Energy



In late February 2014 SNC-Lavalin Inc. announced the appointment of **Preston Swafford** to the roles of Chief Nuclear Officer, President and CEO, Candu Energy, effective March 1, 2014.

Based in Toronto and reporting to the Company's Power Group President, Alexander (Sandy) Taylor, Mr. Swafford will be responsible for growing SNC-Lavalin's nuclear business to meet the needs of its customers for technical services, major refurbishments and new builds across Canada and in key international markets.

Mr. Swafford joins SNC-Lavalin following a seven-

year career at the Tennessee Valley Authority (TVA), where he most recently held the role of Executive Vice-President and Chief Nuclear Officer, Nuclear Power Group. In that position, he was responsible for managing the company's nuclear fleet and providing stable power from six nuclear operating units.

Mr. Swafford joined TVA in 2006 as Senior Vice-President, Nuclear Support, before being appointed Executive Vice-President, Fossil Power Group, a year later. He has also held high-level positions at Exelon Corporation, including that of Senior Vice-President, Exelon Energy Delivery-Operations and Technical Service. Mr. Swafford holds a Master's of Science in Nuclear Engineering from the University of Missouri.

Mr. Swafford has been certified as a Senior Reactor Operator on a U.S.-designed light water reactor. He has served as a member of the Nuclear Safety Review Board (NSRB) for the Ginna nuclear power plant in Rochester, New York, and as Chairman of the NSRB at the Bruce Power site in Tiverton, Ontario. He also serves as a member of the recently formed international advisory group to the Japan Nuclear Safety Institute (JANSI).

L-3 MAPPS to Supply Simulator for Belgian NPP

L-3 MAPPS has announced that it is to supply a full-scope operator training simulator for unit 1 of the Tihange nuclear power plant in Belgium.

L-3 MAPPS will supply a facility equipped with full replica control room panels, employing its graphical simulation tools for the plant models and instructor station.



The three-unit Tihange plant (Image: L-3 MAPPS)

All of Tihange 1's plant systems will be simulated including the reactor, nuclear steam supply system, balance of plant systems, the electrical distribution systems and the instrument and control systems. The electrical grid, including the main generators and transformers, will be modelled with FAST, a product of Tractebel Engineering, the engineering arm of plant owner Electrabel, itself a subsidiary of France's GDF-Suez.

The project will start immediately and will be led by Tractebel Engineering. The simulator is expected to enter service in early 2016.

Tihange 1 is a 962 MWe pressurized water reactor (PWR) that began operating in 1975 and is scheduled to close in 2025. The site hosts two larger PWRs which started up in the early 1980s and are both also due to shut by 2025.

Australia to Build Mo99 Facility

In January 2014 the Australian Nuclear Science and Technology Organisation (Ansto) announced that it had awarded a contract worth AUD83 million ($73 million) to design and construct a new facility to manufacture the vital medical radioisotope molybdenum-99.

Molybdenum-99 (Mo-99) is used in hospitals as the source of technetium-99 in an estimated 45 million diagnostic procedures per year around the world. Produced in research reactors, the radioisotope has a half-life of only 66 hours and cannot be stockpiled. Most of the world's Mo-99 comes from just five reactors in Belgium, the Netherlands, Canada, South Africa and Russia which have have been in operation since the 1950s and 1960s.

Ansto's OPAL reactor, which came into operation in 2006, currently supplies enough Mo-99 to meet Australian domestic requirements. The new Nuclear Medicine Molybdenum-99 (ANM Mo99) processing facility will enable Ansto to significantly increase the output from OPAL, enabling it to make some 20 million doses per year, launching Australia as a major international supplier of the isotope.

Ansto had announced its plans for the new facility in September 2012. Regulatory approval was granted by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) in October 2013. Ansto has now awarded the design and construction contract to Australian construction company Watpac Limited.

Watpac manager Ric Wang said that design work on the facility is would begin in February 2014, with construction scheduled for completion in 2016.

Debris Clearance at Fukushima

At the end of January 2014, Tokyo Electric Power Company (Tepco) released a series of photographs showing progress in the removal of tsunami debris from the damaged Fukushima Daiichi plant.

The first tsunami waves breached sea defences at Fukushima Daiichi about one hour after the magnitude 9.0 earthquake struck on 11 March 2011. Later waves completely overwhelmed the power plant's sea front, carrying debris including cars into the site.

While debris was quickly cleared from roads and paths to allow workers to access the site to help in stabilizing the

damaged reactors, much of the debris remained untouched.

Tepco's latest photos show how the removal of debris - including cars, trucks and building materials - was successfully completed in some areas of the plant adjacent to the sea.

The images on the left show debris left by the tsunami, while those on the right show the same scenes after clear-up (Images: Tepco)



Megatons to Megawatts Program Concludes

The arrival, in December 2013, of the final shipment of low-enriched uranium (LEU) from Russia to the USA marks the successful completion of the *Megatons to Megawatts* program to downblend weapons-grade uranium.

In 1993, the US and Russian governments signed an agreement for the purchase over a 20-year period of 500 tonnes of Russian 'surplus' high-enriched uranium (HEU) from nuclear disarmament and military stockpiles. These were to be bought by the USA for use as fuel in civil nuclear reactors. Under the deal, the USA transferred to Russia a similar quantity of natural uranium to that used to downblend the HEU.

Known as the HEU Agreement, and sometimes referred to as the *'Megatons to Megawatts'* program, it was implemented through a 1994 contract between the US Enrichment Corporation and Techsnabexport (Tenex), a subsidiary of Russian state nuclear energy company Rosatom, which acted as executive agents for the US and Russian governments. After the HEU Agreement was signed the US Enrichment Corporation was later privatized, becoming USEC Inc. Since 2000 the program has been under the US National Nuclear Security Administration (NNSA).

Since 1995, USEC has purchased more than 14,000 tonnes of such LEU, which has involved more than 250 shipments from Russia. This LEU has been used by the USA to fuel its nuclear power reactors, supplying nearly 10 per cent of all US electricity over the past 15 years.

Future Russian supplies

While the Megatons to Megawatts program has now been completed, USEC will continue to purchase LEU from Tenex under a multi-year contract signed between the two companies in March 2011. However, unlike the Megatons to Megawatts program, the LEU supplied will come from Russia's commercial enrichment activities rather than the downblending of Russian weapons material.

Japan Nuclear Regulator Expands

In early March 2914 Japan's Nuclear Regulation Authority (NRA) announced that it had completed its previously announced merger with the Japan Nuclear Energy Safety Organisation (JNES). The move gives the NRA greater resources for processing reactor restart applications.

The NRA was established following the 2011 Fukushima accident to replace the Nuclear and Industrial Safety Agency, itself part of the Ministry of Economy, Trade and Industry, which promoted the use of nuclear energy. With a more independent mandate than its predecessor, the NRA has two pressing tasks: it must oversee the decommissioning work at the Fukushima Daiichi site, and it must process the applications to restart other reactors.

The NRA will benefit in this work by adding the experience and resources of the JNES, which was set up in 2003 as an expert body to inspect nuclear installations and undertake safety analyses. It has already been acting in support of the NRA. The Japanese cabinet approved the merger of NRA and JNES last October.

The JNES was officially abolished yesterday and absorbed into the NRA. Many of JNES's 400 staff are highly experienced and have joined NRA's workforce, taking the NRA's total staff close to 1000. Some of the most experienced staff from JNES are expected to take mentoring roles that help existing NRA staff develop their competency.

Applications have been made to restart 17 of the 48 units idled due to a loss of confidence in Japan's nuclear safety arrangements after the Fukushima accident of 2011. The speed that NRA can independently process these applications under its new rules is partially dependent on its manpower.

NRA chairman Shunichi Tanaka was recently cited

as saying that none of the restart applications are expected to be completed before April.

Cigar Lake Begins Operation

Production has begun at the Cigar Lake uranium mine in northern Saskatchewan, Canada. Start-up of the underground mine was delayed several years due to flooding.

Cameco, the mine's operator, announced in early March 2014, that Cigar Lake's mining system and underground processing circuits "are operational" and that extraction of ore has begun.

This ore is being transported some 70 kilometers by road to Areva's McClean Lake mill for processing through a toll-milling agreement. However, the actual processing of the ore from Cigar Lake at the mill is expected to begin by the end of June.

The McClean Lake mill will produce between 2 million and 3 million pounds of uranium concentrate (770 to 1154 tU) in 2014, increasing output to 18 million pounds (6925 tU) by 2018.

Cigar Lake is the world's second largest high-grade uranium deposit, with grades that are 100 times the world average. In sandy soil, the orebody is being frozen prior to mining to prevent water inflow and improve radiation protection. The ore is being removed by a jet boring system, using water under high pressure to carve out cavities in the orebody with the resulting ore slurry collected through pipes. This is being taken to underground grinding and thickening circuits and then pumped to the surface as slurry, which is then loaded into special containers for the journey to McClean Lake.

Cigar Lake is owned by Cameco (50%), Areva (37%), Idemitsu (8%) and Tepco (5%). The McClean Lake mill is owned by Areva (70%), Denison (22.5%) and Japan's Overseas Uranium Resource Development Company (7.5%).

Development of Cigar Lake began in 2005 and the mine was originally scheduled to begin operating in early 2008. However, its development was delayed by three separate incidents of water inflow, one of which led to the flooding of the entire complex in 2006. Remediation work at the mine was completed in 2011. A uranium mining licence from the Canadian nuclear regulator was issued last June but Cameco delayed the start of operation for additional work on underground ore handling equipment.

Cameco president and CEO Tim Gitzel said, "Cigar Lake is among the most technically challenging mining projects in the world. The start of ore production is a tremendous achievement."

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The Faculty of Energy Systems and Nuclear Science at the University of Ontario Institute of Technology (UOIT) invites applications for a Tier I Canada Research Chair (CRC) appointment. The candidate must hold a PhD in a relevant engineering or science discipline with extensive research experience and demonstrated excellence, both nationally and internationally in areas of nuclear or energy security, with a demonstrated expertise in one or more of the following areas: nuclear non-proliferation; management of nuclear reactor accidents; nuclear emergency preparedness/response for reactor accidents or radiological events (including terrorist activities); homeland sovereignty; state-of-the-art detection techniques for special nuclear materials; security of energy supply (which may include applied knowledge and security issues related to distributed energy sources, modular and advanced nuclear reactor designs and/or nuclear technology for oil sands applications). In addition, the ideal candidate will have significant experience, preferably in an applied research environment, to lead collaborative/interdisciplinary research teams, including successful collaboration with industry, and an ability to attract and mentor graduate students and secure external research funding.

For more information about this position and how to apply, please visit the UOIT Human Resources website at **http://hr.uoit.ca/academic_careers** to review **UOIT 13-340 CRC Nuclear/Energy Security.**

UOIT is an equal opportunity employer and welcomes applications from members of visible minorities, aboriginal peoples and persons with disabilities. All qualified candidates are encouraged to apply; however, Canadians and permanent residents will be given priority. Canada Research Chairs are subject to review and approval by the CRC Secretariat. Further details on the CRC Program can be viewed at **http://www.chairs.gc.ca.**

CNS news

"Continuance" Achieved

The Canadian Nuclear Society has recently received information from Industry Canada that it had been approved for "Continuance" under the new Canada Not-for-Profit Corporations Act (CNCA).

This marks the successful conclusion of more than two years of efforts by a committee of the CNS Council to modify the Society's By Laws to meet the new requirements of the CNCA.

As background, after years of deliberations and consultations with non-profit organizations, the federal government issued the CNCA in 2010. The objective was to make the laws applying to non-profit incorporated organizations more suitable to their particular needs. CNCA also served the purpose of ensuring that non-profit corporations were serving their stated mandate and not being used for other purposes. Prior to the passing of the CNCA non-profit corporations had to meet the requirements of the Canadian Corporation Act (CCA) which are aimed at commercial companies.

Organizations fitting under the scope of the new Act had until December 2014 to obtain what the government called "Continuance" to remain incorporated.

Many of the not-for-profit incorporated organizations are also charities, which brings in a different set of factors addressed in the CNCA. Although those do not apply to the CNS, other aspects of the new CNCA do.

A major question from the beginning of the CNS exercise was that of membership. Under the CNCA only one class of membership is permitted, and all members must have equal voting powers at general meetings. The CNS By-Laws did not specify different classes of membership, but several sections referred to students, retired members, and even organizational members.

The Society engaged the services of a legal company specializing in non-profit organizations, Carters Professional Corporation. Rather than just turning over the task to Carters, the Council Working Group reviewed the existing CNS By-Laws in detail. That stretched the review period over many months. Nevertheless an agreed set of By-Laws was achieved and submitted in December 2013. Notice of acceptance and issuance of Continuance was received from Industry Canada in February 2014.

The revised By-Laws were approved by a Special Meeting of the Membership on Sunday, November 3, 2103. Subsequent to that meeting, the new By-Laws along with the mandatory application for continuance forms were submitted to Industry Canada in February, 2014. The next Annual General Meeting to be held May 25, 2014, immediately prior to the 10th International Conference on CANDU Maintenance being held at the Toronto Convention Centre, will be conducted under the new By-Laws and the statutory requirements of the CNCA.

Annual General Meeting

Sunday, May 25, 2014

Metro Toronto Convention Centre

The 2014 Annual General Meeting of the Canadian Nuclear Society will be held Sunday afternoon, May 25, 2014, immediately before the opening of the 10th International Conference on CANDU Maintenance.

All members are urged to attend.

The order of business will be:

- Election of the Officers and Council for 2014-15
- The Report of the Auditors for 2013
- Appointment of the Auditors for 2014
- Annual reports from Branches, Committees and Divisions

The AGM will be held in Room 103 of the MTCC, beginning at 3:30 p.m.

(Registration to the Conference is not required to attend the AGM)

(Ed. Note: As this is drawn from the report by Branch Affairs chair Syed Zaidi for the January 31, 2014 Council Meeting it is not up to date.)

BRUCE – John Krane

Bruce Branch is planning to present awards at the upcoming April Bluewater District Science Fairs. A cash award of $50 will be presented at the each of the 2 fairs.

The Branch executive will be holding a 2014 planning session shortly to begin making arrangements for meetings and presentations.

CHALK RIVER Branch – Scott Read

Education and Outreach:

Bruce Wilkin will be gearing up to start planning the career night at Algonquin College.

Other Initiatives:

The annual President's Dinner with CNS President, Adriaan Buijs, was planned for February 25th. It will be held again at the Bear's Den in Deep River.

DARLINGTON Branch – Jacques Plourde (by Leon Simeon)

The merger of the Durham (Darlington) and Pickering branches is still in the planning stage.

OTTAWA Branch – Ken Kirkhope

New Executive

Ken Kirkhope became Branch Chair in **December 2013**, succeeding Mike Taylor who was long-serving Chair of the Branch. The current executive, as of **1 January 2014**, is as follows:

Ken Kirkhope -	Chair
Mike Taylor -	**Past Chair**
Fred Boyd -	**Treasurer**
Satyen Baindur -	Program Convenor
Ruth Brinston -	Communications
Jeet Khosla -	Secretary

Meetings

CNS Ottawa Branch members were invited and many attended presentations and workshops from the CNSC speaker series:

- **November 20, 2013** – Dr. Svetlana Selivanova on "State of the Art Cyclotron Production of Technetium-99m"
- **December 11, 2013** - Dr. John Stevenson on "Historical Development Of The Seismic Design Plus Wind/Flood Loading And Design For Nuclear Power Plants".
- **December 17, 2013**, Dr. Abhinav Gupta on "Summary of Activities at the NC State University Center for Nuclear Energy Facilities" and "Structures And Seismic Re-Evaluation And Probabilistic Methods In Establishing Reliability of SSCs"
- **January 13, 2014** - Commissioner George Apostolakis on "The US Nuclear Regulatory Commission and Level 3 Probabilistic Risk Assessments"
- **January 20, 2014** – Dr. Nick Priest on "Do Exposures to Low-Levels of Alpha-Emitting Radionuclides Present a Health Hazard?"

The CNS Ottawa Branch meeting program is being developed by the new Executive. The Branch will itself host a number of presentations by invited speakers in the coming months. The first talk was a presentation by Dr. Jaro Pachner on **February 3, 2014**. The Branch is to hold a combined dinner and presentation later in the spring; as such events have been quite popular and successful in past years.

Education:

A number of members of the Ottawa Branch are contributing as lecturers for a new Nuclear Engineering Graduate Course, at Carleton University this semester. organized by Dr. Glenn McRae.

Members of the Branch Executive have submitted forms to participate as judges at the Ottawa Regional Science Fair, coming in April.

SHERIDAN PARK Branch – Peter Schwanke (Acting)

We plan a change within our Branch executive. After being the Branch Chair for a number of years I would like to pass the torch to Raj Jain, who has graciously volunteered to take on the role! Raj has been a part of the executive since the time Adriaan Buijs was the Branch Chair and I believe he will make an excellent Branch Chair. I in turn would like to assume his role as Branch Secretary so as to still be involved in the Branch activities.

(Ed. Note: This change was approved at the January 31, 2014 Council meeting.)

TORONTO Branch – Andrew Ali

On **Dec. 13, 2013** the CNS Council, approved Andrew Ali, as the Toronto Branch Chair.

Special thanks to Paul Gillespie for his leadership as Toronto Branch Chair for the last several years. Paul will continue to support as a Past-Chair.

Cory Linton will take on the position of Treasurer.

The Toronto Branch is currently recruiting Branch Executives to implement the objectives of the CNS.

12. UOIT Branch – Ray Mutiger

Membership

Registered Membership: 89 as of 2013/03/01
Registered Membership: 114 as of 2013/06/23

Registered Membership: 166 as of 2013/12/06
Facebook Membership: 265 members as of 2013/05/31
Facebook Membership: 368 members as of 2013/01/25

The CNS – UOIT Branch registered members has grown from 114 members as of June 23rd, 2013 to 166 members as of December 6th, 2013. The Branch goal was to increase membership by 10% by the end of the 2013 year. The goal was exceeded by having a membership increase of 45%. The total membership of the CNS – UOIT Branch has increased from 89 members as of March 1st, 2013 to 166 members as of December 6th, 2013.

The registered membership growth for the 2013 year was 86% for the CNS – UOIT Branch. The Facebook presence has growth for the 2013 year was 39%.

UOIT Branch Activities				
Date of Event	**Title**	**Presenter**	**Affiliation**	**Attendees**
01/08/2013	Fusion and Radiation Experiments	Dr. Peter Schwanke	CANDU Energy	32 Students
23/08/2013	McMaster Nuclear Reactor Tour	—	McMaster University	13 Students
30/08/2013	Canadian Workshop on Fusion Energy Science and Technology	Dr. Blair Bromley, Dr. Hossam Gaber, Ray Mutiger, and Gabriel Aversano	Canadian Nuclear Society	21 Students 56 Industry
03/09/2013	Amazing Race	UOIT Engineering Society	UOIT	~300 Students
12/09/2013	Involvement and Club Connect Fair	Student Experience Centre	UOIT	~500 Students
27/09/2013	LaTeX Scientific Document Writing	Margarita Tzivaki	UOIT	—
18/10/2013	Cameco Fuel Manufacturing Tour	CNS – UOIT Branch	CNS – UOIT Branch	16
18/10/2013	Pandora's Promise Film Screening	CNS – UOIT Branch	UOIT	
25/10/2013	PTVM Reactor	Reuven Rachamin	Helmholtz-Zentrum Dresden-Rossendorf	—

WESTERN Branch – Jason Donev

On November 13th 2013, Terry Jamieson from the CNSC joined Dr. Duane Bratt, Harie Vradenburg and Dr. Jason Donev to serve as a panel with Dr. Dave Layzell moderating. We watched the video *Pandora's Promise* with an audience of roughly 120 people from the public. The event was put on by the University of Calgary's student energy club (ISEEESA) at the ConocoPhillips Auditorium and was very well received.

ABC Tech hosted a workshop on Fusion in Calgary AB, on October 25th 2013. Duane Pendergast, Cosmos Vousinous, Isaac Faubert, Stacy Muise, Jaafer Kahni, Riley Fedechko, Caleb Tymo and Jason Donev attended and represented the CNS. We learned about the state of fusion research and the business opportunities that fusion would present for Alberta.

Dr. Duane Bratt presented at the CNA conference 'New Reactor workshop" November 7th in Edmonton AB. A number of U of Calgary students attended as well.

Stacy Muise, Ellen Lloyd and Jason Donev attended a conference called the *"2013 Energy Literacy Conference"* in Kananaskis put on by the Centre for Environment-Economy Learning. **November 3-5th**. We participated actively in discussions and presented twice. This has led to collaboration with the museum of science and technology in Ottawa.

Dr. Jason Donev went to Ottawa and taught a *Nuclear 101* course with Dr. Jeremy Whitlock and Dr. Doug Boreham. The participants were largely employees of the CNSC, the course was well received with 45 people taking the class. We had many lively discussions.

The *"ATA Science Conference 2013"* was held in the Radisson Hotel, Edmonton South, from November 14 to 16, 2013. The conference was organized by the Science Council of the Alberta Teachers' Association (ATA). Aaron Hinman, Gary Lewis and Rob Varty worked at the CNS display booth in the conference. They operated the display booth on November 15 and 16. The booth featured Geiger detectors with computers, and numerous handout materials. Duane Pendergast and Shaun Ward helped with the preparation of equipment and supplies for the booth.

Obituaries

Dr Richard Verrall 1947-2013

Richard Verral, a key figure in Canada's Fusion Fuel Program in the eighties, passed away peacefully on Thursday, November 14, 2013 at the Deep River Hospital, Deep River, Ontario, after a long battle with the after-effects of a stroke.

Richard was born in Winnipeg, Manitoba on August 8, 1947 and lived in Sanford, Manitoba until he was 12 years old. In 1959, the family moved to Winnipeg and Richard went to Vincent Massey and then on to the University of Manitoba.

He had a stellar academic career, graduating in Honors Physics, placing first in his class, achieving the gold medal. He obtained his doctorate in Solid State Physics from Harvard University followed by a two-year post doctorate study at Kings College in Cambridge, England.

In 1979, he joined Atomic Energy of Canada Limited at its Chalk River Laboratories. I hired Richard to bring mathematical rigour to the test results we were anticipating from the Fusion program. He was a lead member of the team that performed in-reactor, real-time measurement of Tritium behaviour in candidate lithium ceramic fusion blanket fuel, and developed Lithium ceramic fabrication techniques.

The program demonstrated the superior properties of Li_2ZrO_3 for Tritium production in-reactor tests at Chalk River, and internationally. Richard and Joan Miller authored a key paper that elucidated for the first time the mechanism for Tritium release from Lithium ceramics[4].

With the wind-up of the Fusion program, Richard became a team member of the program that simulated high-burnup UO_2 fuel, permitting inexpensive scoping tests for fission-gas release and grain growth without the necessity for in-cell analysis[5]. He also contributed substantially to understanding the behaviour of high-burnup UO_2, supporting the existing commercial nuclear power program

Unfortunately, Richard had heart trouble which led to a stroke in his early fifties, and a period of declining health. Richard was an avid duplicate bridge player and for many years was the director of the club in Deep River. Chess was a close second, playing on line when he couldn't find partners in the town. He had a quirky sense of humour and was a reliable player on the Mets softball team at Chalk River. Richard will be sadly missed by his legion of Canadian and international friends and colleagues.

(from Dr. Ian J. Hastings, edited)

John (Ian) Edward Wilson

Past President CNS; Past Vice President – Technology CNA

Members of the Canadian Nuclear Society (CNS) were greatly saddened with the death of Past President Ian Wilson on January 6, 2014. He was one of the first Presidents of the CNS to serve after incorporation, holding office from 2002-2003 after serving for two years as CNS Secretary.

Less well known, however, is his previous career at the Canadian Nuclear Association (CNA).

He started his career in Canada at Ontario Hydro in 1969. He served as Manager of Public Hearings in the late 1970s and 1980s, and he was responsible for Ontario Hydro testimony before the Royal Commission on Electric Power Planning and the Porter Commission.

He was seconded to the CNA in 1985. At that time, the CNA was at something of a crossroads. The industry was coming under increasing criticism from some members of the public, and Ontario Hydro was experiencing a string of increasingly expensive delays in the completion of the Darlington nuclear station. It was felt by some in the industry that the CNA needed additional resources beyond its then-small permanent staff to manage all of the public issues that were starting to confront the industry. This need was enhanced by the large nuclear reactor accident at Chernobyl Unit 4 north of Kiev in Ukraine the following spring,1986.

Ian's coordinated the nuclear industry response to a number of public enquiries resulting from that traumatic event' including: the Ontario Nuclear Safety Review; the Ontario Hydro Demand/Supply review; and the environmental assessment review of the concept of geologic storage of high level used nuclear fuel waste, commonly referenced as the Seaborne Panel.

In addition Ian was also instrumental in developing the CNA's first large scale public communications program. The Chernobyl accident had evoked a large loss of confidence by the Canadian public in the safety of nuclear facilities. Working with CNA Communications Vice President Rita Dionne-Marsolais, they developed a comprehensive national strategy to reach all Canadians by a multi-layered strategy of television advertising, direct mail, newspaper and radio advertising and editorial pieces.

The goal of the program was very simply stated: to restore public confidence in the safety of Canada's nuclear reactors. The ongoing program was high-

lighted by three flights of television commercials in 1988, 1992-3, and 1994. At each stage, the results were carefully measured by polling done by Angus-Reid (now Ipsos-Reid). By the summer of 1994 when the program was terminated, support for nuclear power in Canada had approximately doubled, and opposition to had approximately halved.

Ian's role in this campaign was critical. Using professional agencies to develop the message it was Ian's responsibility to ensure complete technical accuracy of the information.. He also innovated with Ms. Dionne-Marsolais the first comprehensive national public opinion survey of attitudes to nuclear power. Previously this had never been done before, but under Ian it became an annual activity maintained up to 2010.

He also oversaw the writing and production of fact sheets on various aspects of the industry. These were used not just by the association but also by the information offices at the various nuclear plant sites across the country.

In conclusion, his effect on the public image of Canada's industry was profound, particularly so at a time of the delays with Darlington, and the consequences of the Chernobyl accident. It was that rebuilding of public confidence that allowed the federal government to renew the CANDU Owners funding agreement in 1990 to provide technical research funding in support of Canada's nuclear industry for years to come.

by Colin Hunt

Adi Dastur

A personal remembrance from Jerry Hopwood

It is with sadness that the reactor physics community marks the passing of our AECL colleague and retiree Adi Dastur, who passed away on January 17, 2014.

Adi was one of the pioneers and experts in the behavior and modelling of CANDU reactor cores. Over a long career at AECL, he innovated many of the features of CANDU reactor physics that our community now takes for granted. He was the originator of the original CANDU core physics codes – for example, CERBERUS – from which today's core models were derived. He was also the originator and inspiration for the demonstration of the CANDU reactor's ability to recycle fuel – one of our important business advantages. Finally, Adi led one of the most important investigations of nuclear safety following the Chernobyl accident, when he was one of the first in the world to identify the safety system design flaw that led directly to the accident's severity.

Adi received the CNS Outstanding Achievement Award in 1994.

Adi was as humble as he was generous. He was incurably happy and optimistic, and took as much pleasure in mentoring others as he took in his exceptional studies. He was one of our industry's true pioneers.

We will miss him.

2014 Nominations for CNS Council

Members of the Canadian Nuclear Society (CNS) will elect the society's governing Council for 2014-15 at the upcoming Annual General Meeting. That meeting will be held prior to the beginning of the *10th International Conference on CANDU Maintenance,* on Sunday, May 25, 2014 at the Metro Toronto Convention Centre.

All members of the CNS wishing to stand for election to the CNS Council or its Offices must submit their completed nomination forms no later than **23:59, Monday, March 31, 2014.**

Members wishing to stand for election to Council can receive the forms by contacting the CNS Office. In addition, all members wishing to stand for election to Council are encouraged to read the document "Council Roles and Responsibilities" posted in the Members' documents section of the CNS website.

For further information regarding nominations and election to the CNS Council, contact:

John Roberts, CNS Past President: alcherny@tnt21.com

Colin Hunt, CNS Secretary: colin.hunt@rogers.com

CNS Office: cns-snc@on.aibn.com

Calendar

2014

Apr. 27-30 — **Canada - China Conference on Advanced Reactor Development**
Niagara Falls, ON
website: www.cns-snc.ca

May 4-6 — **Nuclear 101 Course**
Hamilton, ON
website: www.cns-snc.ca

May 25-27 — **10th International CNS Conference on CANDU Maintenance**
Metro Convention Centre
Toronto, Ontario
website: cns-snc.ca

June 15-19 — **American Nuclear Society - Annual Conference**
Reno, NV, USA
website: www.ans.org

June 23-26 — **PHWR Safety 2014 / CANSAS-2014 CNSC, AECL, IAEA, CANSAS**
Ottawa, Canada, Lord Elgin Hotel
Contact CNS Office: www.cns-snc.ca
email: cns-snc@on.aibn.com

Aug. 24-28 — **19th Pacific Basin Nuclear Conference (PBNC 19)**
Hyatt Regency Hotel,
Vancouver, BC
website: www.cns-snc.ca

Aug. 24-28 — **38th Annual CNS / CAN Student Conference (embedded in PBNC 19)**
Hyatt Regency Hotel,
Vancouver, BC
website: www.cns-snc.ca

Sept. 28-Oct. 3 — **Physor 2014**
Kyoto, Japan
For information: CNS office
cns-snc@on.aibn.com

Oct. 26-31 — **Nuclear Plant Chemistry Conference 2014 (NPC-2014)**
Sapporo, Japan
website: www.npc2014.net

Nov. 5-7 — **3rd International Technical Meeting on Small Reactors**
Ottawa, Ontario, Canada
Ottawa Marriott Hotel
website: www.cns-snc.ca

Nov. 9-13 — **American Nuclear Society - Winter Meeting**
Anaheim, California
website: www.ans.org

Important Message re CNS Membership

Have you renewed your CNS membership for 2014? If so, thank you! Your membership is essential to support the on-going activities of the Society. You can very easily renew your membership on-line.

Log in to your personal CNS profile at **https://cns-snc.ca/accounts/cns_member_renew** (or via the Membership page of the CNS website, **www.cns-snc.ca**).

If you have any questions, please send an e-mail to: **cns-snc@on.aibn.com**.

Ben Rouben,
CNS Executive Director and Membership Chair

Note importante à propos de l'adhésion à la SNC

Avez-vous renouvelé votre adhésion à la SNC pour 2014 ? Si oui, merci bien ! Votre adhésion aide à soutenir les activités de la Société. Vous pouvez très facilement renouveler votre adhésion en ligne.

Accédez à votre compte SNC personnel à **http://www.cns-snc.ca/fr/membership** (ou bien par le lien que vous trouverez sur la page d'adhésion sur le site de la SNC, **www.cns-snc.ca**).

Pour toutes questions, veuillez envoyer un courriel à: **cns-snc@on.aibn.com**.

Ben Rouben,
Directeur exécutif de la SNC et président du comité des adhésions



MESSAGE FROM THE CONFERENCE GENERAL CHAIR



On behalf of the Canadian Nuclear Society and the CMC 2014 Organizing Committee, it is my great honor to request that you join us at the 10th International Conference on CANDU® Maintenance. CMC 2014 is the only major nuclear conference to be held in the Greater Toronto Area this year, and it will bring together subject matter experts from operating utilities and service providers for intensive discussion on various topics of importance to the nuclear industry.

CMC 2014 is a 'flagship' conference as it is the first time that the CNS Utility Engagement Team has been fully involved as an integral part of the Organizing Committee. The conference will focus on the future; while making use of our past and present experience to meet the Needs and Interests of the Operating Utilities (NIOU).

The concept of NIOU was introduced at CMC 2011, where utilities identified issues of importance to them and service providers undertook to find solutions. That approach continues with this year's conference to provide the ideal environment for open and free exchange of ideas, and to incubate solutions to address tomorrow's challenges and opportunities.

Keeping up with tradition, the conference will include the very popular CANDU® Course, an excellent technical program with four parallel sessions each day, the Trade Show involving leading service providers, strong student engagement, and a variety of networking opportunities.

We are encouraged by the range of technical and plenary topics as laid out in the Preliminary Program, available at www.cmc2014.org. Now it's your turn to help make the conference a great success – become involved by encouraging registration in good numbers, by sponsoring the conference in an area of your choice, and by exhibiting and demonstrating your company's strengths in support of the industry.

I look forward to welcoming you to the conference at the MTCC, May 25-27, 2014 with the objective of ***Revamping the Technical Strength of Our Industry.***

Sincerely,

Vinod Chugh
Conference General Chair

CMC 2014 will bring together subject matter experts from Operating Utilities and Service Providers under the banner of CANDU® Maintenance, with the objective of ***Revamping the Technical Strength of Our Industry.***

Four key drivers to achieve and sustain high performance will be the primary focus of the Plenary and Technical Sessions: **Policy and Vision, Processes and Tools, Plant Equipment and Reliability, and People and Skills.**

Bruce Power

Policy and Vision

Led by Bruce Power



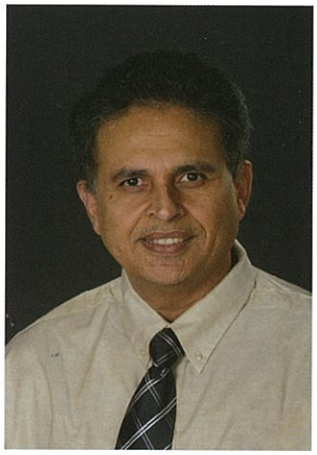
Gary Newman

Chief Engineer and Vice-President of Engineering, Bruce Power

Énergie NB Power

Processes and Tools

Led by NB Power



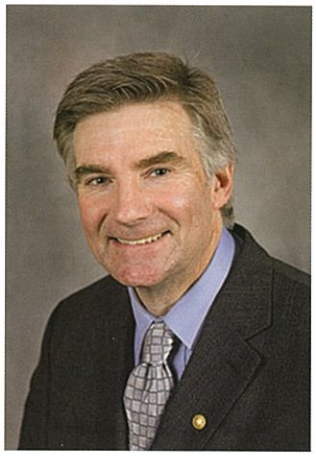
Alnoor Bhaloo

Chief Nuclear Engineer and Engineering Director, NB Power

ONTARIO POWER GENERATION

Plant Equipment and Reliability

Led by Ontario Power Generation



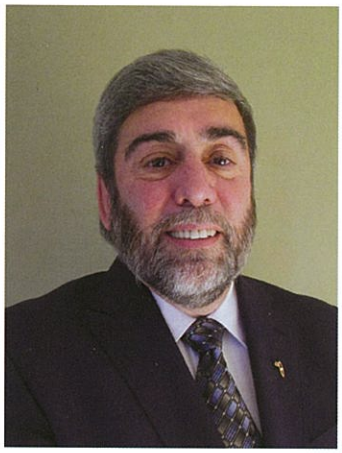
Mark Elliott

Senior Vice President and Chief Nuclear Engineer, Ontario Power Generation

CANADIAN NUCLEAR SOCIETY ® SOCIÉTÉ NUCLÉAIRE CANADIENNE

People and Skills

Led by Canadian Nuclear Society, NOM Division



Jacques Plourde

Chair, CNS Nuclear Operations and Maintenance Division

Register to Participate – to network with participants and renew or establish new industry contacts

Provide Sponsorship – to become recognized as a "Leader of the Industry"

Book a Trade Show Booth – to showcase your company's products and services

For all details go to

www.cmc2014.org

Revamping the Technical Strength of Our Industry

CANADIAN NUCLEAR SOCIETY ® SOCIÉTÉ NUCLÉAIRE CANADIENNE

Hosted by the Nuclear Operations & Maintenance Division (NOM) of the Canadian Nuclear Society

PBNC 2014

19th Pacific Basin Nuclear Conference

2014 August 24-28 Vancouver, Canada

Fulfilling the Promise of Nuclear Technology around the Pacific Basin in the 21st Century

Canadian Nuclear Society / Société nucléaire canadienne

Pacific Nuclear Council – PNC

Natural Resources Canada / Ressources naturelles Canada

Canada

NU The Future is NU. Canadian Nuclear Association

PBNC-2014 will:

- *showcase the advancement of nuclear technology in power generation, health science, and environmental stewardship;*
- *discuss challenges facing nuclear technology;*
- *highlight future development.*

- **400 papers, and 40 plenary and keynote speakers from the Pacific nuclear countries**
- **4 Luncheons, 2 Receptions, 1 Banquet**
- **W.B. Lewis Lecture, Honours & Awards Luncheon, Student Program, Guest Program**
- **Conference Exhibition (open 3 days plus opening reception)**



Sponsorship and Exhibition opportunities still available!
CONTACT: **Doug Burton, doug_burton@cameco.com**

PBNC-2014 VANCOUVER 2014

Important due dates for authors:
Draft Paper: 2014 Feb. 28
Final Paper: 2014 June 01

www.pbnc2014.org

PBNC-2014 Updated Conference Announcement

PBNC-2014
Vancouver, British Columbia, Canada
2014 August 24-28

The Canadian Nuclear Society, the Canadian Nuclear Association, and Natural Resources Canada, in collaboration with the International Atomic Energy Agency, are proud to host the 19th Pacific Basin Nuclear Conference (PBNC-2014) August 24-28, 2014, in Vancouver, Canada, under the aegis of the Pacific Nuclear Council.

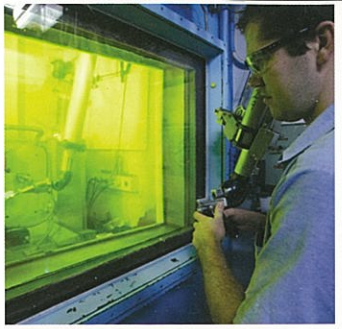
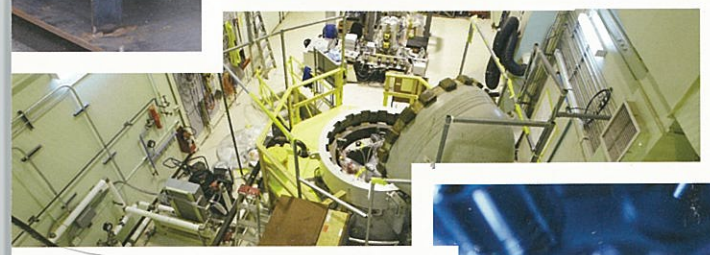
The Pacific Basin Nuclear Conference (PBNC) held biannually, is the premier global nuclear conference and exhibition bringing together senior industry executives, senior government officials, international energy organization leaders, and technical experts from the Pacific Rim and Europe. More than 600 delegates are anticipated for the Conference. Canada previously hosted this conference at Banff, Alberta in 1998 – one of the most successful PBNCs. The most recent PBNC 2012 was held in South Korea.

The Conference Theme is "***Fulfilling the Promise of Nuclear Technology around the Pacific Basin in the 21st Century".*** PBNC-2014 will: (i) showcase the advancement of nuclear technology in power generation, health science, and environmental stewardship; (ii) discuss challenges facing nuclear technology; and, (iii) highlight future developments.

Plans have progressed extremely well and we are poised to have a great conference:

- 400 technical abstracts received from 20 countries.
- 40 Plenary and Key Note Speakers from Pacific Nuclear Countries
- Sponsors and Exhibitors >60% Committed
- Cultural and Guest Events Planned
- Student Conference Call for Papers Issued.

Please visit the web site http://pbnc2014.org to view information and to register and participate in the Program.

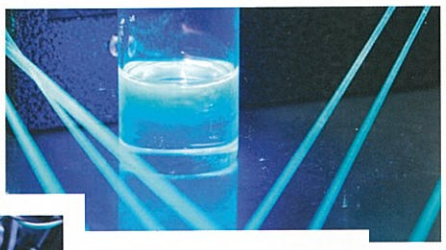
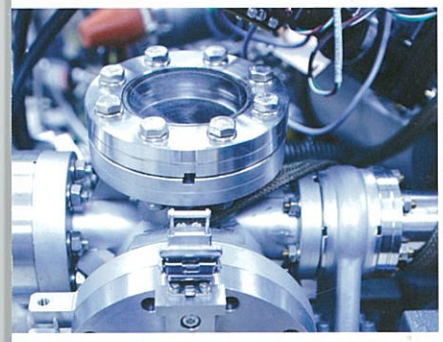
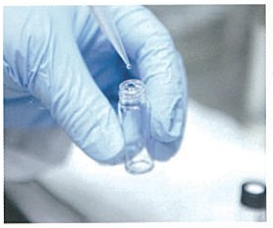





AECL can help advance the innovatio
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Health Physics Neutron Generat
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