CANADIAN NUCLEAR SOCIETY

Bulletin

DE LA SOCIÉTÉ NUCLÉAIRE CANADIENNE

JUNE 2009 JUIN VOL. 30, NO.2

- 30th Annual CNS Conference
- McMaster Reactor Turns 50
- History – The First Carbon-Uranium Piles
- W.B. Lewis Memorial Lecture

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Tumultuous Times!

It is often said that we live in interesting times and 2009 is certainly no exception. Much is happening, some good, some not so good. The good includes the 50th Anniversary of the McMaster Nuclear Reactor (MNR) and Natural Resources Minister Lisa Raitt's announcement of $22 million in funding for upgrades to the reactor. Also, Infrastructure Ontario announced that AECL is the lead bidder for Darlington New Nuclear.

Whether good or bad, the Minister of Natural Resources announced that AECL is for sale. I have already stated my views on this in the September 2007 edition, Vol. 28 No. 3. Privatisation, per se is not so much important as how a company is managed. However, what is bad is the timing of the announcement. It resulted in Infrastructure Ontario suspending indefinitely the bidding process for Darlington New Nuclear. Financial guarantee for cost over-runs was the key item not met by the other bidders; with uncertainty in ownership, and in particular the uncertainty of Federal financial guarantees to honour a fixed price project, the Province took the prudent stand. Unfortunately, the announcement by the Federal government has cast a shroud of doubt for AECL's ability to sell its ACR in Ontario, sending a tsunami of doubt across the related infrastructure of Ontario manufacturing and construction jobs.

The very bad, however, is the unplanned extended outage of the Nuclear Research Universal (NRU) that may last several months. This has lead to yet another global health crisis because, as a result of a previous Federal government decision, there is no back-up facility in Canada to produce Molybdenum-99, the essential medical isotope that is shipped around the world for use in medical imaging, diagnosis and treatment of disease.

MDS Nordion, in a press release on June 1, 2009, urged the federal government and AECL to complete the MAPLE project, bringing in a consortium of experts if AECL lacks the expertise. There is also an article posted on the MDS Nordion website, written by the former MAPLE nuclear commissioning manager and published in Nuclear Engineering International (October 2, 2008). The article claims that the MAPLE is one of the safest reactors in the world. Steve West, President of MDS Nordion said in its press release, "The current NRU shutdown - and the shutdown of November 2007 - illustrates the fragility and unpredictability of the global medical-isotope supply system, and highlights the requirement for new research reactor capacity to deliver a reliable long-term supply of medical isotopes." He also stated that completing the MAPLE is the best solution, something that expert witnesses attested to during the hearings held in June by the Standing Committee on Natural Resources of the House of Commons (see note from the Publisher).

The MNR in Hamilton can help if requested with only minor changes to hold special targets. It has been done before, producing Mo99 during a prolonged outage of the NRU three decades ago.

The NRU supplies more than 30% of world supply and 70% of Canada's supply of Mo99. However, each MAPLE reactor can produce enough Mo99 to meet 100% of the world demand, and with two MAPLE reactors, a back-up supply is available should one require maintenance.

There is no quick and easy solution to the current shortage of Mo99. The fragility of the ageing NRU has been known for a long time, and it resulted in Parliamentary high drama following its outage in November 2007. With all eyes then focussed on the Federal government, there was time for the political leaders to encourage the development of back-up strategies including completion of the MAPLE reactors. However, it appears that the political leaders have been focussed more on their own survival instead of the survival of the people who need those medical isotopes.

In This Issue

We commemorate the 50th anniversary of the McMaster University Nuclear Reactor (MNR) with a report on the celebrations, special announcements and a brief look at its history and the many valuable contributions it has made to science, industry and medicine. It is truly a marvel of Canadian ingenuity and excellence in science and has evolved not only as a research tool but a successful commercial operation providing neutron imaging service, activation analysis, medical isotopes and quality assurance for industry and government agencies.

There are two conference reports: the 30th CNS Annual Conference, which attracted a record attendance (450) in Calgary, and the 2nd Climate Change Technical Conference held at McMaster University in Hamilton. A report on the 2009 Honours and Achievement Awards is included.

In keeping with tradition, the ***W.B. Lewis Memorial Lecture*** is included in this edition. Delivered at the CNS Annual Conference by **Dave Torgerson**, Emeritus Senior Technology Advisor for AECL, it is entitled *The Future Nuclear Vision*.

CNS Member **Don Jones** has prepared a very informative article on wind and nuclear on the Ontario power grid, and clarifies some of the myths that unfortunately drive decisions. We also have the regular commentary from **Neil Alexander**, president of the Organization of CANDU Industries, who offers his views on communication with the public on nuclear energy matters.

We have included an important technical paper that defuses what has been a long-standing safety issue on Large LOCA margins in reactors with positive void coefficients. Thanks to **Dan Meneley** and **Ajit Muzumdar,** winners of the 2009 CNS Innovative Achievements Award, for putting the issue into better perspective. Another paper with multiple authors is also included entitled *Making Ionising Radiation A Real Experience For High School Science Students*.

We have the usual General News and CNS News, including news of our members. No Bulletin would be complete without an end page, and again, always provocative and entertaining, **Jeremy Whitlock** offers what might be an interview with the vampire (maybe) in ***Endpoint***.

We hope you enjoy! As always, your letters, articles and comments are welcome.

The past few months have been very active ones for the Society and very public ones for the Canadian nuclear program.

The Society

The highly successful CNS Annual Conference in Calgary was the culmination of more than a year's planning and hundreds of hours of volunteer effort by dedicated members. This wasn't just another conference; it was a venture into the western part of our great country, where the CNS had not gone before. (There were, long ago, CNA conferences in the west in which the CNS took part but this was the first time the CNS on its own had ventured out of eastern Canada.)

Along with the Conference, the Society held its Annual General Meeting in Calgary, with a respectable attendance. That heralded the "passing of the torch" from Jim Harvie to Dorin Nichita, who expressed his wish that the restructuring of the Society proposed a year ago would continue. He emphasized the Society's role in education and proposed that we re-examine the publication of a peer-reviewed Journal. (See his message in the CNS News section.)

The Canadian nuclear scene

Over the past few months the media has had a feeding frenzy with story after story on the medical consequences of the termination of the MAPLE program and the problems with NRU. They have been sad and embarrassing. Sad because the promise of an assured supply of desirable radioisotopes for nuclear medicine was shattered and embarrassing in the implication of incompetence by all involved.

With an apparent cone of silence applied by both AECL management and the federal government the most insightful information about the situation has come in hearings held in June by the Standing Committee on Natural Resources of the House of Commons.

Chris Heysel, manager of the McMaster Nuclear Reactor, informed that MNR had produced Mo 99 back in the 1970s when NRU was down for several months to replace the calandria. He said they had offered to do so again if given the request and financial support to make the necessary changes. Given that a relatively modest investment could assure a backup production of Mo 99, sufficient to meet Canada's needs, it would seem to be an obvious insurance policy. Instead the government chooses to talk to the few other suppliers in the world, despite their unreliability and higher cost.

Dan Meneley pointed out that the existence of a small positive reactivity coefficient was insufficient grounds for the CNSC to prevent operation of MAPLE since all CANDU type power reactors have that characteristic. Harold Smith, formerly on the MAPLE project, reported that CNSC staff had prevented tests that could have explained the observed behaviour. Instead they demanded that it be resolved solely by analysis, a process that went on for years. Jatin Nathwani, of University of Waterloo, summed up the situation with the phrase that it was a case of "regulatory inflexibility".

With the new management at the CNSC, that "inflexibility" appears to have disappeared. I believe that the Commission would be prepared to consider a new application for MAPLE based on a revised safety case.

Nevertheless, AECL management has not budged nor has it ever explained why it suddenly terminated the MAPLE project last year. For those of us who can remember, it seems very similar to the AVRO Arrow fiasco of decades ago.

Canada pioneered the use of radioisotopes for medical purposes, beginning with the world's first Cobalt 60 therapy machines in 1951, and has been a world leader ever since. It would be a crime to throw away that capability and heritage.

A replacement for NRU

The government's stance on NRU – to abandon it in six years – is a denigration of over 60 years of pioneering and world-class nuclear research in this country. Without a reactor the Chalk River Laboratory will die. Canada was almost the first to have a nuclear reactor and we have been involved in nuclear research and development since the mid 1940s.

Although the recent media attention has been on NRU as a producer of medical isotopes, it is primarily a research reactor, which has been essential for the development of the CANDU line of nuclear power reactors. It is also the source of neutrons used to conduct world-recognized research in metallurgy, biology, nano-science and other fields.

The Canadian Association of Physicists foresees the collapse of neutron-based research if there are no plans for the replacement of NRU and has issued a media release urging the government to take a long-term view. Scientists currently involved are, reportedly, already looking at other countries.

In my view the CNS should join the debate with a sound and convincing brief to the government in support of a new NRU.

Fred Boyd

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~ Cover Photo ~

View of the MNR core showing the classical blue glow of Cerenkov radiation in the reactor pool.

– Photograph courtesy of McMaster University.

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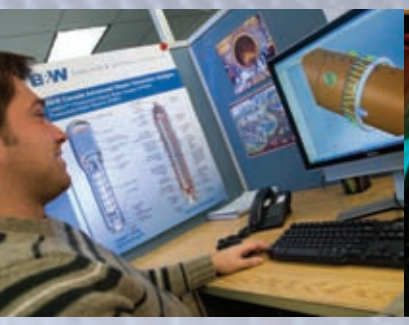


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McMaster Reactor Celebrates 50th Anniversary

Federal Minister announces new grants for nuclear research

by Fred Boyd

On May 1, 2009, McMaster University in Hamilton, Ontario, formally celebrated the 50th anniversary of the McMaster Nuclear Reactor, one of the oldest operating reactors in the world, which started operation on April 4, 1959.

Among the celebrities participating in the relatively short formal ceremony in the morning was Lisa Raitt, Minister of Natural Resources Canada, who took the opportunity to make the following announcement.

"Natural Resources Canada, in partnership with the Natural Sciences and Engineering Research Council of Canada (NSERC) and in collaboration with Atomic Energy of Canada Limited (AECL), will provide almost $6 million in grants over the next three years to fund 23 Generation IV research projects at universities from Nova Scotia to British Columbia."

(Generation IV refers to nuclear power reactor designs which will provide greater safety, more efficiency, and less possibility of diversion of nuclear material to non-peaceful purposes. Several countries are pursuing different approaches. Canada is focusiing on super-critical water-cooled designs.)

McMaster University president Peter George commented that the federal government's investment in nuclear research will lead to new inventions, treatments and increased knowledge for nuclear safety and will aid the development of highly qualified personnel for the nuclear renaissance underway.

Complementing that ceremony there was a special luncheon attended by current and past staff associated with MNR, a number of representatives of companies and organizations that use or had used the reactor, provincial MPPs and others. During the luncheon a two-minute video, titled, *The Core of Discovery* was played highlighting the current use of the reactor. That is available on the website: *mnr.mcmaster.ca* along with much other information about MNR.

In the afternoon there was a cake-cutting ceremony in the library.

The reactor, the first university reactor in the British Commonwealth when it was built, was the result of a major effort by Dr. Harry Thode, then a professor at McMaster. Thode had been a member of the Montreal Laboratory during the Second World War even though he carried out his work on the analysis of fission products at McMaster. He later became president of McMaster University. He envisioned a high quality, multipurpose facility to support the emerging technology of radioisotope medicine, as well as world-class physics and engineering research and it has lived up to his vision.

This anniversary came close to not happening. Back in 1995 the McMaster administration of the day had decided to shut down the reactor after a grant from NSERC was terminated. Researchers and others associated with the reactor created an outcry. In 1996, after a change of administration and following the development of a business plan to develop income, it was decided to upgrade the reactor and continue its operation. A central element of the business plan is the production of Iodine 125 used in the treatment of prostate cancer. Another on-going commercial use is neutron radiography of airplane turbine blades. These activities have not interfered with the use of the reactor for research.

See the article in this issue reviewing the accomplishments achieved with the McMaster Nuclear Reactor over its first half century.

Minister of Natural Resources, Lisa Raitt, and McMaster University president Peter George, pose for the camera after the 50th Anniversary ceremony for the McMaster Nuclear Reactor in Hamilton, May 1, 2009.

McMaster Nuclear Reactor building.

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MNR – The Beginnings and Innovations

by Ric Fluke

Having established a clinical research laboratory to investigate the use of radioisotopes in the diagnosis and treatment of disease in 1951, McMaster was already a pioneer in nuclear applications as an important part of engineering, science and medicine. Chalk River produced radioisotopes at that time for McMaster's nuclear science program and it was soon realized that a large neutron source such as in a nuclear reactor would have applications in many areas including research, health and industry. The University, with financial support from government, industry and AECL, decided to build the McMaster Nuclear Reactor, or MNR. John Diefenbaker, Prime Minister of Canada, officially opened the MNR on April 10, 1959.

The history of medical isotope development and production at McMaster is well known. It produces half the world supply of I-125 used in the treatment of prostate cancer and also produced Mo-99 three decades ago during an extended outage at Chalk River. However, there have been other innovations in a multitude of other disciplines.

Early studies using the MNR involved neutron diffraction in solid-state physics and inelastic scattering in crystals. More importantly, as a national facility it brought the best scientists, engineers and students from vast and diverse fields including medicine, allowing learned discussions and some break-through innovations.

An extension of NAA (Neutron Activation Analysis) is Prompt Gamma NAA (PGNAA) where gammas emitted during neutron capture are examined instead of delayed gammas. The technique is non-destructive and extends the sensitivity of NAA by several orders of magnitude. Dr. Denis Shaw, Professor Emeritus, and his team at McMaster use MNR for PGAA, looking at various problems in the distribution of boron, gadolinium and samarium in terrestrial and lunar rocks ("Moon Rocks") in meteorites.

Another NDE application using neutron is known as neutron radiography. NRay Services, a company located just down the road from the reactor in the Dundas, Ontario uses neutrons at the reactor and has turned this technique into a commercial success by examining turbine blades used by the aircraft industry – every aircraft turbine blade that goes into a North American jet is examined at MNR. Moving from taking "pictures" with neutrons researchers at Mac use real time three-dimensional neutron radiography to make "movies" with neutrons. This technology is a growing application for inspections and quality assurance and McMaster has the only such facility in the world.

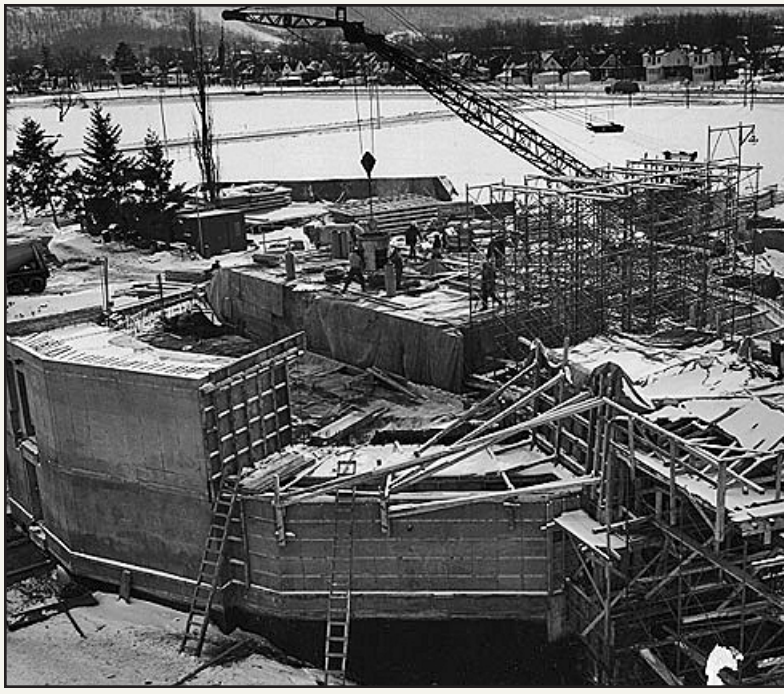
The MNR has allowed many advances in the earth sciences. An Ar-40/Ar-39 method is used in geological dating which has a much wider age range compared to traditional C-14 methods. An associated dating technique, electron spin resonance (ESR) was developed by McMaster using the MNR. This technique is unique in North America and was used recently by McMaster geologists Dr. Henry Schwarcz and Dr. Jack Rink to challenge the popular belief that *Homo erectus* disappeared from the earth more than 250,000 years ago. Their examination of fossils found in lava rock, thought to be 300,000 years old, revealed that that this genus of human beings lived as recently as 27,000 to 53,000 years ago. "It is the first time anywhere in the world that evidence has been found that both *Homo erectus* and *Homo* sapiens were alive at the same time."

With government and industry support, the future looks bright for the MNR. At present, it appears that the MNR may be used to produce Molydenum-99 to help ease the current isotope crisis worldwide. As Chris Heysel, Director of Nuclear Operations and Facilities, puts it,

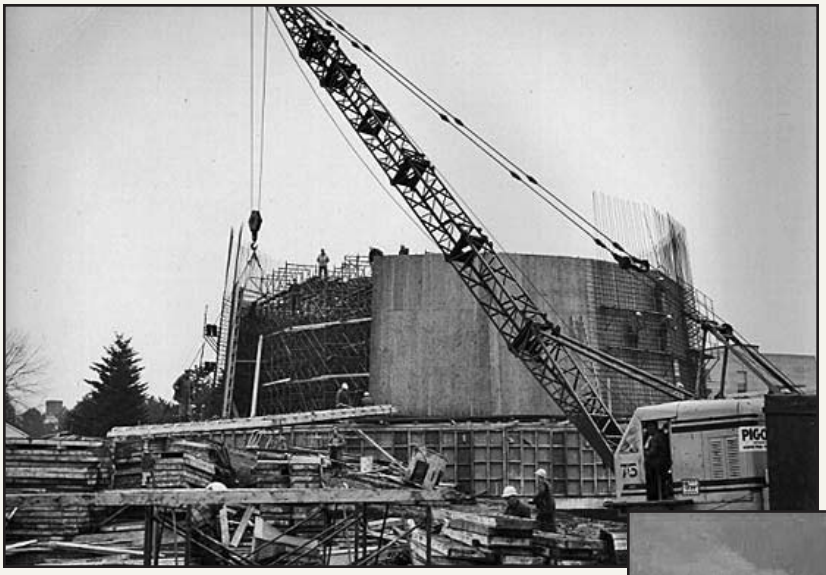
> *"The feeling here at McMaster is that we know we can help – we have done it before… Given that the facility here on campus belongs to Canada we are duty bound to help if we can. In the mission statement of the University it says - we serve the needs of our community and our society – so offering up help on this issue is at the core of what the University is about. If we are not part of the right or the best solution for this issue that's fine - we are willing to offer our support to any solution which will have a positive patient impact."*

[Photos courtesy of McMaster University]

Building the MNR.



View of the MNR construction site, February 1958



◄ *March 20, 1958*

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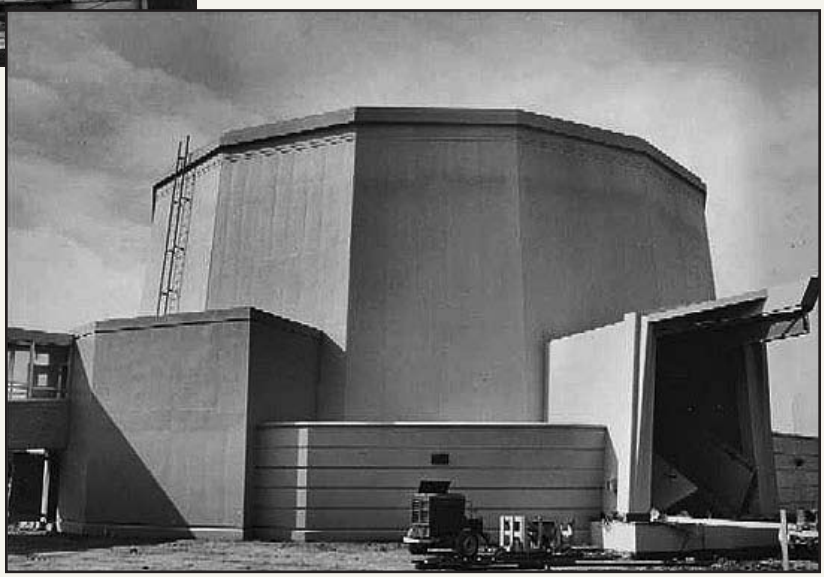

Inside the MNR

◄ *Bill Fleming, first director of MNR and Jon McDougal, first manager or superintendent seen examining the core structure.*

[*Note: visit the MNR website for more information, view a virtual tour, or to arrange a visit, at* www.mnr.mcmaster.ca]

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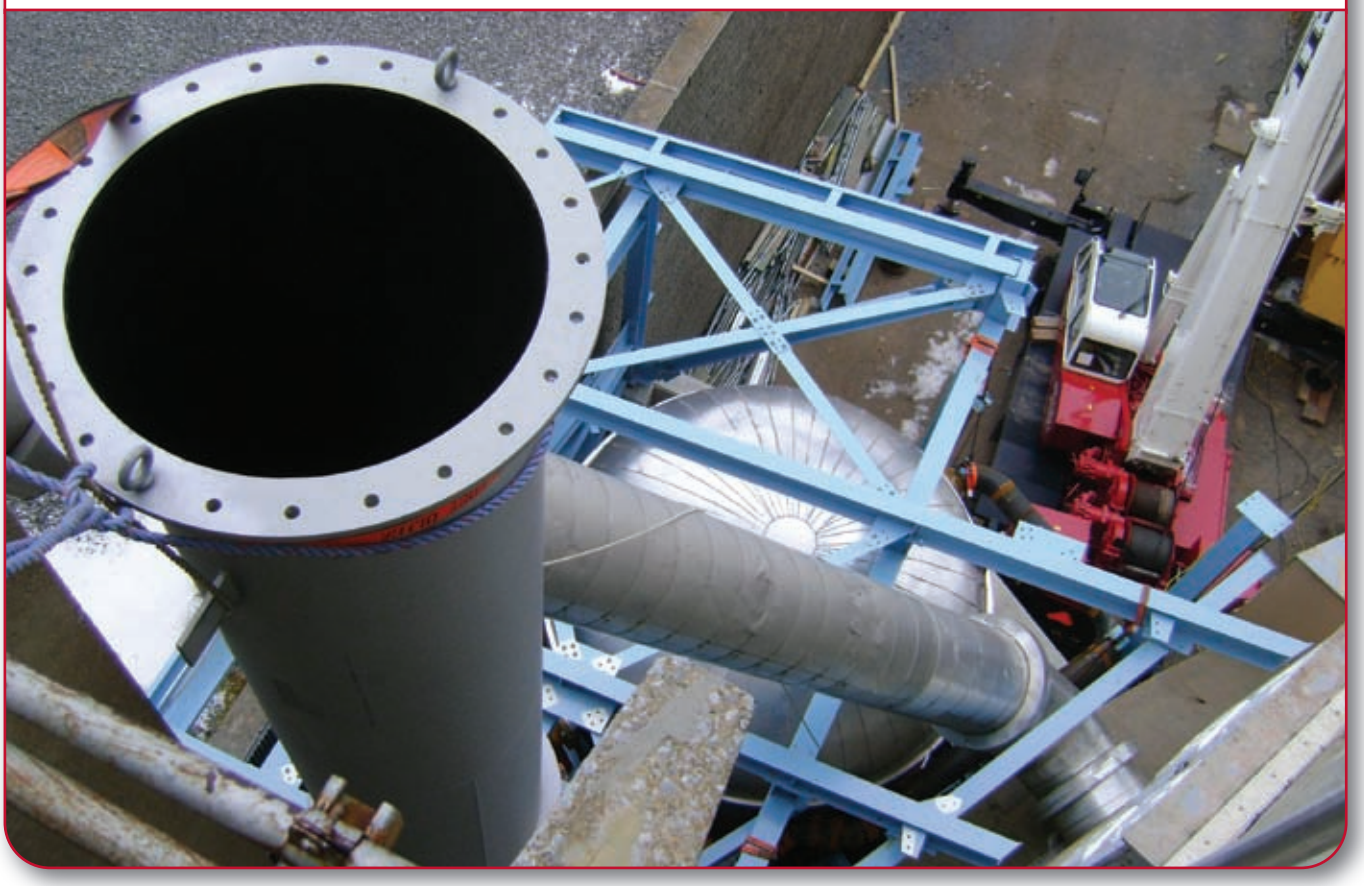

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On picking your message and finding the right words.

By Neil Alexander

President, Organization of CANDU Industries

In the near future there will be significant announcements about the nuclear Industry in Canada. Whatever the announcements are you can be certain that the anti-nuclear groups will be active. We will need to deal effectively with their issues if we are to prevent them from derailing the process.

Our industry is incredibly technical and calls on the very best scientists and engineers to lead it. Unfortunately great scientists and engineers are not necessarily strong communicators. More worryingly some do not consider communication to be important. Obviously this is a generalization. We do have the likes of Duncan Hawthorne who understand that free and open communication on issues that people care about are important. The fact that he is also technically adept and very eloquent is an amazing bonus. But this exception proves the rule as demonstrated by the positive affect he has had on our industry.

For many in the industry the approach to communications has been to stay silent and to keep stories about our industry to a minimum. This is the easiest approach as it restricts ignition points and prevents those nasty people in the media from lighting fires. But much like forestry management, if you restrict the number of fires, you end up building stocks of fuel so that when fires do break out they are much harder to control.

To refer to Duncan Hawthorne again he once told a conference I was at that people will never trust nuclear technology but they will trust the people that run it. (Or something quite close to that). By hiding from the media and the public we have built up a fuel of mistrust that we must now manage very carefully.

Contrast this to the anti-nukes who get out there amongst the population and speak. It doesn't matter whether they are right or not, the fact that they are present wins them support. We must get out there and do the same.

But before that there are a few things we need to know about communications and the media. Firstly my experience of the media (and recently that has been quite extensive) is that they are very sincere people ardently trying to report information as fairly and as accurately as they can. When they get nuclear issues wrong it is because we have failed to communicate properly, that failure causes confusion, confusion causes fear and fear stimulates the anti nuclear articles.

So we need to ask ourselves what has caused this lack of understanding. I am not a communications expert and have done no studies on this subject but it appears to me that there are some analogies with the work that I do on preparing winning proposals.

There are two key factors in writing winning proposals that may be relevant to this situation. The first is to write about the things that matter to your customer. The second is to do it in a language that they recognize and makes them feel comfortable. Sounds simple doesn't it but the sad fact is that most people like to write about the things that they think are important and in their own language.

Take for example the issues we often talk about that make the CANDU's great, use of natural uranium and on-line refueling. These are both features and are of little interest to the general public. The public may be interested in a lower electricity prices or avoiding unstable countries getting nuclear weapons but natural uranium, no way.

In proposal preparation we avoid these pitfalls of "internal focus" by standing back and identifying aspects of "positive differentiation". These are issues that the customer cares about but which make us different in a positive way. It is a challenging discipline and should never be taken lightly. Once "positive differentiation' has been established the focus of everything done is around those issues. The process simultaneously identifies issues that the competition might use as their positive differentiation and this makes it possible for inoculating arguments to be prepared.

Just at the moment the issue that people care about more than anything else is jobs. As a secondary issue they are worried about climate change. Can we as an industry demonstrate that we create more jobs than anyone else? Yes we can. In the famous words of a previous Darlington VP the only more labour intensive way of producing electricity in the community is to put people on tread mills and make them run for their power. What is more a successful export business will create manufacturing jobs. Can we demonstrate that we have a lot to offer in reducing the production of greenhouse gasses? Again yes we can. We are positively differentiated on the two issues that are of most important to the general public!

But the anti-nukes have in the past been very good at identifying their "positive differentiation" and making sure that the agenda is focused around these issues. This means that they are always forcing us to defend against their issues. Anyone should know that winning when you are forced into a defensive role is very difficult. Historically they have traded heavily on risk, cost and "waste" disposal. We can answer all these issues very easily but defending against them does not win us any points. We need to control the agenda and get it back to the issues that people care about.

Now to language. Word choice is incredibly important in directing the behaviour of people. Words actually create mental images that are in many cases more powerful than a picture because they create persistent mental images. The wrong choice of words can create serious problems; the right choice of words

will solve those problems. Call someone a hard worker and that is good, call them a workaholic and it is bad. Hands on, good, micromanager bad etc etc.

I think everyone will agree with me on word choice in general applications but there will be those that believe that technical issues are different. Those people should read David Sanborn Scott's book "Smelling Land" about our Hydrogen Future to learn how a simple mistitling of a shortage of available oil products as an "energy crisis" can lead to inappropriate and unhelpful actions. (Sadly this is something that occurs all too often).

Word choice has been one of our industries weaknesses. We talk a lot about poisons to describe elements that shut down nuclear reactions. Then we talk about disposal of "wastes". I have heard the containers used for the storage of used fuel described as coffins and sarcophagi. No wonder people are scared.

Some things are so ingrained that we may not even realize that it means one thing to us and another to our audience. I learned this when I was working on medical radioisotopes. Contamination to me was stuff that got out but my FDA auditor thought it was stuff that got in. When we say containment to the general public do they think about stopping stuff getting in or stopping stuff getting out?

As with the messaging the anti-nukes are good at picking the right words. They know that people are interested in the environment. Environment is a good word for the imagination to work on and the image is always positive. For me it is snow capped mountains with glaciers and clean crisp air (and ski lifts with no one but me and my family on them). Others will think of clean beaches and palm trees or quiet little farmhouses in the forest. Everyone will have their own image and with the exception of the team from Top Gear (a program out of the UK largely about gas guzzling supercars) they will all be positive.

As soon as an anti-nuclear campaigner has established themselves as an "environmentalist" they have stolen the high ground and are in control of the agenda. Positively differentiated and with great language they are a formidable challenge.

But anti-nuclear campaigners are not environmentalists. In the words of Patrick Moore these people are not for something they are just against things. Their main achievement to date has been to sustain the use of fossil fuels for power production. Imagine if they had been more successful in derailing the growth of nuclear power, not only would we have 430 more producers of greenhouse gases and mercury but we would have no alternative technology available to us. Global warming would already be worse and we would have no prospect of stopping it. Wow they must be proud. Luckily for the environment they were not that successful. Luckily for us anti is a bad word with negative connotations.

And their areas of positive differentiation are largely of their own creation and have ever weaker standing with their audience.

My conclusion is that with a little thought, some careful choice of words and a lot of activity in our communities the battle for public support is ours to win.

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30th CNS Annual Conference

- record attendance at Calgary event

by Fred Boyd

A record number of delegates, sponsors and exhibitors combined to make the 30th Annual Conference of the Canadian Nuclear Society, held in Calgary, Alberta, May 31 to June 3, 2009, a very successful event.

When, two years previously, it was decided to "go west" for the 2009 conference, there was considerable trepidation, since most nuclear activity in Canada is in the east. However, whether it was the activity in Alberta for possible construction of nuclear plants or just the desire to experience the west, the conference drew the largest attendance yet, over 450 delegates plus about 50 exhibitors, surpassing even the numbers that descended on Saint John, New Brunswick in 2007. (Perhaps Toronto has lost its charm !)

Armand Laferrère

Bill Robinson

Following the pattern of recent years, the conference began with an excellent reception on the Sunday evening where CNS president **Jim Harvie** welcomed everyone. Given the large space of the Telus Convention Centre the reception, as well as all the meals, was held in the same area as the exhibits, which enhanced the viewing of the many displays.

The Conference officially began the Monday morning. Following a further welcome, Jim Harvie introduced **Frank Oberle**, MLA for Peace River, who was standing in for the Minister of Energy, Mel Knight. Although oil and gas continue to be the backbone of the Alberta economy, he said, the provincial government is open to new ideas, including nuclear. However, it will be private investors who will decide, not the government, he stated.

Referring to climate change he noted that Canada emits just 2% of the world's GHG and Alberta contributes just 5% of the Canadian total. Nevertheless Alberta is looking seriously at carbon capture and storage technology because 50% of its electricity is derived from coal-fired plants. Regarding the nuclear debate in the province he reiterated that the government would not choose.

Then **Duncan Hawthorne**, CEO of Bruce Power, took the podium as moderator of the opening plenary session. In his brief introductory remarks he mentioned just returning from the 20th Anniversary celebration of WANO (World Association of Nuclear Operators) held in Russia. He commented that he sensed a new open-minded public attitude about nuclear power.

In his introduction of the first speaker, **Armand Laferrère**, CEO of Areva Canada, Hawthorne noted that this would be Laferrère's last engagement in Canada as he is being transferred to head Areva's activities in Russia.

Laferrère began by referring to the current economic recession, commenting that many of the 300 nuclear power projects proposed a year or two ago had been cancelled or deferred. The current activity, he noted, is almost all in Asia or Russia. However, he suggested, there is a need for new electrical generation and building nuclear plants could help to get out of the recession.

On the question of technology he noted that customers were becoming more selective. Decisions are being made on a business model not political, he stated, with more interest in established designs. Finally, he observed that governments and national safety authorities are working together to deal with complex designs.

The next presentation was by **Bill Robinson**, Senior Vice-President at Ontario Power Generation, who commented that he was more or less standing in for Pierre Charlebois who, he said, retired the previous day and was already on a cruise.

He began with an overview of OPG operation, noting the mandated shutdown of the coal-fired stations by 2014, increased wind generation and the possibility of converting some of the coal stations to burn biomass. The OPG nuclear plants have been performing very well with five of the units having a capacity factor in 2008 of over 90%.

Work on the environmental assessment for the planned two new units at Darlington is well underway, he said, with a decision expected in 2011. At the same time studies are continuing on the possible refurbishment of Pickering B and similar work has begun for Darlington.

Hawthorne invited questions before the break and an early one was directed at him, regarding reports that Bruce had actually to pay for excess generation rather than lower generation. He replied that varying the power of the units has several negative aspects, both technical in the strain on the systems and organizational in the additional workload on the operation staff. Therefore, they prefer to pay the excess generation cost.

David Hay, CEO of New Brunswick Power, continued the opening plenary after the break. He began by commenting that New Brunswick was moving from being "hewers of water" to "hewers of electrons", referring to the provinces plan to increase electrical generation as well as other major energy projects. The refurbishment of the Point Lepreau station is underway but somewhat behind schedule, he noted, adding that it is essential to "get it right". NB Power is also looking at new hydro and wind generation and the development of a "smart grid", eyeing the growing demand for electricity in the New England states.

Next was **Richard Florizone**, of the University of Saskatchewan and chair of the Saskatchewan Uranium Development

Partnership Task Force. Currently, Saskatchewan is the world's largest producer of uranium, he noted. The province would like to be involved in further processing but there is currently a surplus worldwide of conversion facilities, he said, while there may be some possibilities in enrichment. Further public consultation is essential, he commented, before the province moved forward with nuclear or uranium projects.

The view from Alberta was provided by **Harvey André,** chair of the Alberta Expert Panel on Nuclear Energy, which issued its report earlier in the year. He described the role of the province in the possible building of nuclear power plants as cooperating with federal authorities on environmental reviews, examining social impact, and managing the political implications. There has been little reaction to the Panel's report, he commented.

Closing out the session, **Glenna Carr**, chair of the Board of Directors of Atomic Energy of Canada Limited, provided an overview of the various activities of the company, which range from major tasks such as refurbishment to on-going services to support CANDU Owners Group. She noted the research and development capabilities of the Chalk River Laboratory, a collaborative program with Natural Resources Canada on waste management and the production of radioisotopes (that was before the recent NRU problem).

Glenna Carr

David Torgerson

Gerald Grandey

The Canadian Nuclear Safety Commission has agreed to review the design of the Enhanced CANDU 6 and has completed the first level of review of the new ACR 1000, she said. Contracts have been issued for long lead-time components for the new (ACR1000) plants expected to be built at the Darlington site. In closing, she stated that AECL is looking to hire 700 additional staff, mostly professional.

At the Monday lunch, **Tim McMillan**, MLA for Lloydminister, Saskatchewan, provided a further look at that province's interest in nuclear energy and uranium. His province still has positive economic growth, he noted, despite the global recession. A major interest is to obtain more "value added" for the province's uranium. A major technical review is going on regarding carbon capture and storage to reduce the province's CO_2 emissions. Saskatchewan wishes to be a major player in Canada's nuclear future, he stated in closing.

The Monday afternoon and the mornings of Tuesday and Wednesday were devoted to the technical program with five parallel sessions, along with the Student Conference, and a special "Western Focus Seminar" organized by Alberta CNS members.

Monday evening saw the Nuclear Achievement Awards dinner *(see separate report)*

The period after the Tuesday lunch was devoted to the annual W. B. Lewis lecture, this year presented by **David Torgerson,** recently retired Senior Vice-President of AECL. (The lectures are sponsored by AECL and are named after Dr. W. B. Lewis, the head of the Chalk River Laboratory from 1946 to 1973.)

Under the title *The Future Nuclear Vision* he began by stating that we are on the threshold of unprecedented changes in the global nuclear community. The various factors affecting these changes he classified into the following main drivers: 1) environmental concerns, 2) economics, 3) population growth, and 4) energy security.

A major consequence, he said, will be the expansion of operating nuclear power plants from the few hundred we have today to a few thousand by the end of this century. This expansion will present challenges and opportunities in every area of the nuclear industry, including design and development, construction, supply, operations, maintenance, regulation and safety, decommissioning, and the entire nuclear fuel cycle. The creative innovation that characterized the birth of the nuclear power industry is needed, he asserted, in all these areas to address fully the challenges and opportunities.

(Torgerson's paper is reprinted in this issue of the CNS Bulletin.*)*

The first part of the Tuesday afternoon plenary session was devoted to presentations on uranium mining developments, led off by **Gerald Grandey**, CEO of Cameco Corporation, who titled his talk: *Cameco: A Vertically Integrated Uranium Mining Company.*

He began by noting that at university he was an environmentalist and anti-nuclear protestor. Then, after looking into the matter, realized the objections to nuclear were over-stated and that it offered many benefits, such as no GHG and low fuel costs. But, he emphasized, he remains an "environmentalist". The CNS can and should provide sound information, he urged.

Looking at uranium reserves, he noted that two Cameco mines can meet the needs of all existing and expected nuclear power plants in the western world. But, he added, on a world scale existing mines can supply only 80% of the projected demand.

In closing he urged his audience to be more publicly engaged and to provide sound information.

A different perspective was provided by **Don Falconer**, Vice President of Aurora Energy Resources Inc., a "junior" uranium mining company, which, he noted, was founded in 2005 but is now a subsidiary of Frontier Development Corporation Inc. They have a high-grade deposit, similar to Cigar Lake, in Labrador, he reported, which they plan to mine as an open pit. At the planned production of 10,000 tonnes per day they expect the deposit to last for 15 years.

Rounding out the overview of uranium mining was **Nick Carter**, Vice President of The Ux Consulting Company LLC. Worldwide uranium production has not grown significantly for many years, he stated. However, there are a number of areas in which expansion is underway, such as Kazakhstan, Canada, Russia, USA and several countries in Africa. His supply / demand curve showed a major gap after 2020 unless a number of new mines come into existence.

The second part of the Tuesday afternoon plenary session was on the subject of *New Frontiers in Nuclear Technology* with the first presentation, by **Brian Doucette**, Director, Environmental Excellence, Suncor Energy Inc focussing on *How technology will address the chal–*

lenges of the oil sands industry. After noting that Suncor is the largest operator in the oil sands he showed slides of the process. The "environment" he reminded the audience is long cold winters, short hot summers.

Only 20% of the deposits can be mined from the surface. Those are mined using very large shovels and equally large trucks. For most deposits the bitumen is extracted using steam pumped underground. It is a very energy intensive process, he noted. Considerable effort is expended to manage the tailings ponds with plans to reclaim them in the near future.

Duncan Hawthorne

Romney Duffy, Principal Scientist at AECL began with the question, "Is there enough uranium?" noting that the threat of climate change dictates that there will be more nuclear power plants, as many as 4000 by 2100. This will require reprocessing which some countries are trying to restrict on proliferation grounds. There are several myths about nuclear energy which must be dispelled, he argued, noting: nuclear waste is unsolved; cost too high; cycle produces CO_2, uranium resource too small; radiation is bad; nuclear power leads to bombs. Energy is a worldwide problem, he said in closing, and must be tackled cooperatively.

Speaking just before the media storm that erupted that week about the shutdown of NRU, **Steve West**, President of MDS Nordion, provided a very positive overview of the medical use of radioisotopes, noting sterilization, diagnosis, therapy. The market, he commented, is being driven by ageing and obesity, which have increased the incidence of chronic diseases. MDS Nordion is constantly innovating, especially in the development of personalized medicine using isotopes.

Closing out the session was a presentation by **John Waddington**, onetime CNSC now associated with the company International Safety Research, on the topic *Institutional Failure: Are Safety Management Systems the Answer?"* Studies have revealed that over 70% of "accidents" are caused by human error, which, he stated, usually means an institutional failure. After providing a couple of examples of major accidents he commented that the automotive industry is trying to reduce the accident rate by half and suggested that the nuclear industry should do the same.

Tuesday evening delegates boarded buses for a "Rodeo Fun Night" at a rodeo centre just outside the city. *(See accompanying photos.)*

Wednesday morning saw the continuation of the parallel technical sessions and continuation of the Western Focus Seminar and Student Conference. *(The awards for the winning student papers are reported in the CNS News section.)*

At the time of printing the conference program the speaker for the Wednesday luncheon had not been finalized. Then, despite the many pressures she was facing, the Minister of Natural Resources Canada, Lisa Raitt, agreed to do so, and it was arranged for her to address the convention delegates by video conferencing. With just a half hour to go her office informed the conference organizers that she would not be able to do so. One of the group had the inspiration to ask **Duncan Hawthorne** to say a few words. Typically, he said yes, and gave a short extemporaneous but inspiring talk on the need to do everything well to ensure the future of our nuclear program.

Two plenary sessions shared the Wednesday afternoon, one on Refurbishment, the other on Regulation.

John Sauer, Vice-President, Bruce Power, began the refurbishment session with an update of the Bruce A Units 1 and 2 Restart. He noted that the steam generators in both units had been replaced. The old pressure tubes and calandria tubes of both reactors have been removed and the installation of new calandria tubes in Unit 2 is about to begin. He mentioned a number of aspects that had gone well and other that could have been done better. Among the former was the decision to keep the rebuild crews separate from operation, including access. Among the lessons learned was the need to do ALL of the engineering before tackling any job.

He made an intriguing comment that it might have been more efficient to replace the entire reactor structure, calandria and all, instead of replacing the tubes and feeders.

A report on the progress of the refurbishment of the Point Lepreau unit was provided by **Gaetan Thomas**, Vice-President, New Brunswick Power, He noted that Point Lepreau was the first of the CANDU 6 design.

The end fittings, feeders, and pressure tubes have been removed and removal of the calandria tubes is underway. The turbine rotor that fell into the harbour has been returned from inspection in the UK. Although the project is somewhat behind schedule, due primarily to complications with the feeder and pressure tube removal, it is moving forward and some time has been recovered.

From across the Pacific ocean, **Tae Ho Lee**, Vice-President of Korea Hydro and Nuclear Power, provided a status report on the refurbishment of the Wolsong 1 unit, which was just shutdown in April 2009 after operating at 93% capacity factor in 2008. The refurbishment plan is largely based on that for Point Lepreau with a scheduled completion date of July 2010.

Rounding out the refurbishment session, **Claude Drouin**, Deputy Director, Gentilly 2, spoke about the proposed refurbishment of the Gentilly 2 unit, which has been in planning for several years. The plan to replace the feeders and tubes is similar to that at Point Lepreau. In addition Hydro Québec will replace the control computers. The refurbishment is scheduled to take place over 2011 and 2012.

The final plenary session, focussed on "regulation", was chaired by **Michael Binder**, President of the Canadian Nuclear Safety Commission, who startled the audience by playing stirring "cowboy" music and a slide saying "Good, Bad, Ugly". He was the sheriff, he commented.

He then introduced **Sheila Leggett**, Vice-Chair, National Energy Board. The NEB, she explained, has three roles: regulating international power lines and electricity exports; providing advice to the government on energy matters; and, partnering with other agencies. With a slide she showed that most electrical and gas connections go north and south. An update of the NEB publication *Energy Futures Report* will be issued this summer. The agency is supporting the development of "smart grids" as an aid to reduce greenhouse gas emissions.

Scott Thon, President of AltaLink, explained that his company is Canada's only privately owned transmission company.

Already serving over 80% of the province's population, he said they plan to build lines in advance of generation. They are also looking into the development of "smart grids".

Sean Russell, Vice-President, Nuclear Waste Management Organization, described the program to develop a siting process for long-term management of Canada's used nuclear fuel. He reminded the audience that the federal government had accepted NWMO's proposed Adaptive Phased Management approach in 2007. Now the organization is looking for communities willing to accept a waste facility.

The final speaker of the conference was **Phil Jennings,** ADM in the new Major Projects Management Office. He explained that the role of his office, which was created in late 2008, is to coordinate the various regulatory roles of the federal government in order to expedite approvals for large complex projects. Nuclear power plants would fall into that description.

Thanks to the efforts of Murray Stewart and Frank Doyle, the conference was generously supported by a number of sponsors. Listed alphabetically they were: Aecon; AltaLink; AMEC; Anric; AREVA; Babcock & Wilcox Canada; Black & McDonald; Bruce Power Alberta; Cameco; Canadian Nuclear Association; Canadian Nuclear Safety Commission; E.S.Fox; HSL Nuclear; Hitachi; Hydro Québec; Kanata electronic Services; Kinetrics; NLI; Ontario Power Generation; Power Workers' Union; Saskatchewan Ministry of Energy and Resources; SNC Lavalin Nuclear; Shaw; TransCanada; Wardrop; Westinghouse. Most also had displays.

The conference was organized by a large committee chaired by Dorn Nichita assisted by Ben Rouben. Murray Stewart and Krish Krishnan handled the plenary program while Wei Shen headed the committee for the technical program. The Student Conference was organized by Guy Marleau while Duane Pendergast chaired the committee that organized and ran the embedded Western Focus Seminar.

The 2010 CNS Conference will be held in Montreal from May 30 to June 2. Plan to be there.

At the Rodeo

Scenes from the Conference

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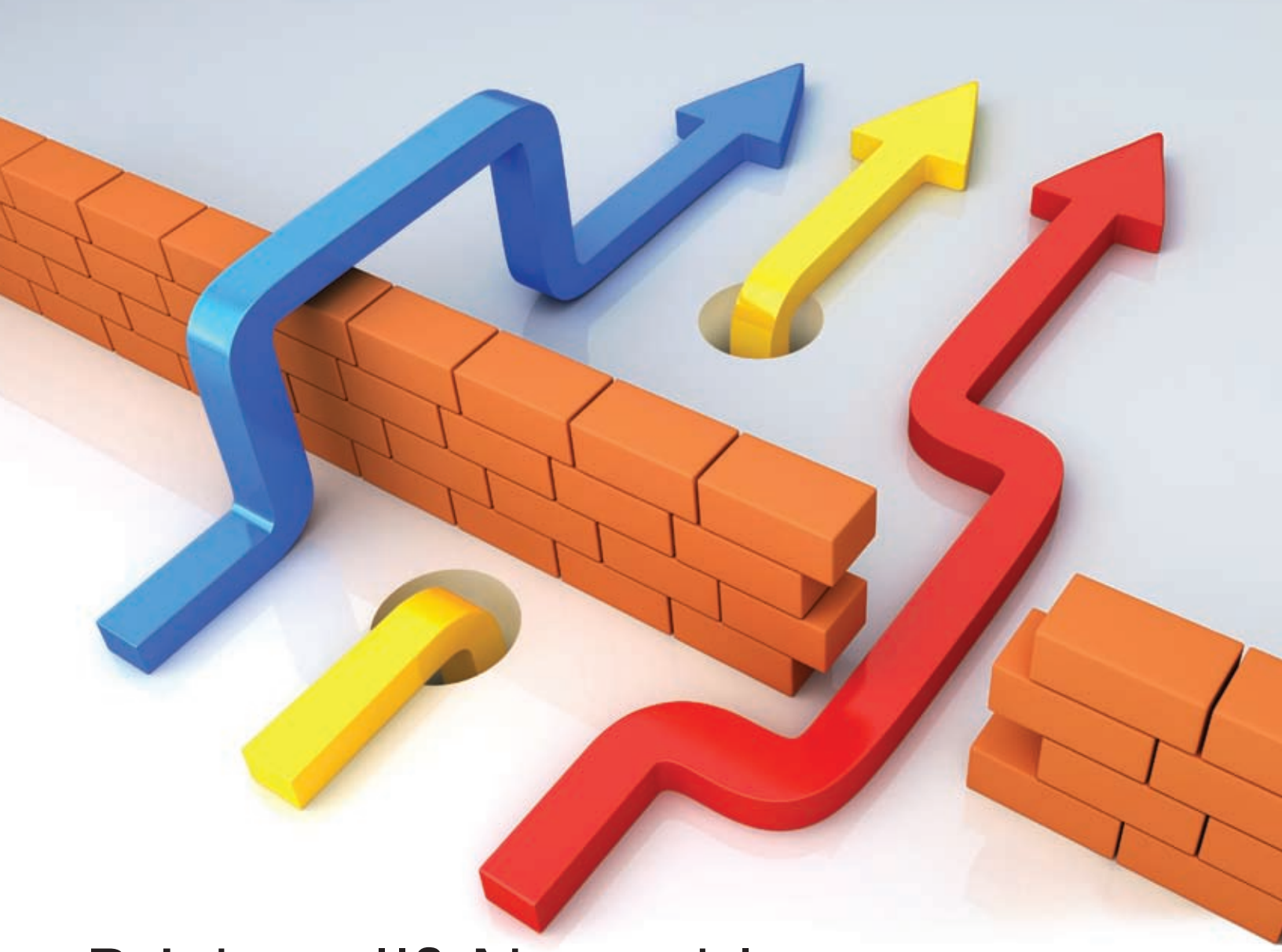

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Canadian Nuclear Achievement Awards

Each year the Canadian Nuclear Society and the Canadian Nuclear Association join forces to award individuals or groups who have made significant contributions to the Canadian nuclear program.

The 2009 awards were presented at an Awards dinner held in Calgary, Alberta on Monday, June 1, 2009, the first day of the 2009 CNS Annual Conference. Six awards were given this year.

Outstanding Contribution Award

Richard W. Barnes

The Outstanding Contribution Award recognizes Canadian-based individuals, organizations or parts of organizations that have made significant contributions in any field related to the beneficial uses of nuclear energy. These contributions may be either technical or non-technical. Contributions toward improved public safety are specifically included.

Richard Barnes has worked tirelessly since the 1970's in developing and advancing Pressure Boundary quality management, and codes and standards in support of the Canadian and international nuclear industries. Mr. Barnes has become a leading international authority in his field. His work on Pressure Boundary and the associated Codes and Standards touches on the very heart of the CANDU nuclear technology. He has also provided oversight and strategic direction for the development of standards in his capacity on the CSA N286 Executive and Technical committees. He is a leading voice in numerous international committees and is working toward harmonizing Pressure Boundary codes and standards among many countries.

Active in the ASME Richard is presently a member of the Standards Committee of the ASME Boiler and Pressure Vessel Code, Chair of Section III, the Subcommittee on Nuclear Power, Vice Chair of the CSA N285 General Requirements for Pressure Retaining Systems and Components in CANDU Nuclear Power Plants Technical Committee among others.

Mr. Barnes has been recognized for his contribution to the nuclear industry by being awarded the ASME Dedicated Service Award and the highest ASME nuclear award, the Bernard F. Langer Nuclear Codes and Standards Award. His achievements were further honoured when he was elected to the ASME grade of Fellow in 2007.

Citation:

For his commitment and dedication to advancing the Pressure Boundary quality management, and Codes and Standards both in Canada and at the international level over many years.

Richard Barnes (L) receives the Outstanding Contribution Award from Colin Hunt representing the Canadian Nuclear Association.

Innovative Achievement Award

Ajit Muzumdar and Daniel Meneley

The Innovative Achievement Award recognizes significant innovative achievement or the implementation of new concepts, which display clear qualities of creativity, ingenuity and/or elegance, and embody an impressive accomplishment in the nuclear field in Canada.

For many years the issue of the Large LOCAVoid Coefficient of Reactivity for the CANDU has generated much discussion for the natural uranium fuelled CANDU. The subject has generated decades of research, debate and often misconception. Occasionally, the very future of the natural uranium fuelled CANDU design has been threatened by perspectives on the issue.

Ajit Muzumdar (L) and Dan Meneley (R) display their Innovative Achievement Awards which were presented by Jim Harvie, 2008 – 2009 president of the Canadian Nuclear Society.

Dr. Ajit Muzumdar and Dr. Dan Meneley took up the challenge of putting the CANDU Void Reactivity into context. The product of their work, a CANDU Owners Group report (COG-07-9012), "Large LOCA Margins & Void Reactivity in CANDU Reactors" , is a must read for anyone in the nuclear industry. In their report, Aj and Dan examine the issue from a number of perspectives. The report is written in language that will appeal to the scientist and executive alike. In an innovative look at the issue, the report compares margins of safety of the CANDU reactor design and other light water designs using a set of indices that have never been used before.

Ajit Muzumdar and Dan Meneley are worthy recipients of a CNS Innovative Achievement Award. Their work forms an important part of the knowledge retention effort for CANDU, and has provided a basis for discussion of the future of the natural fuelled uranium CANDU going forward.

Citation

To Dr. Ajit Muzumdar and Dr. Dan Meneley for innovative and outstanding work to put the CANDU Large LOCA void reactivity issue into the proper context and perspective for the future.

Education and Communications Award

Claudia Lemieux and Claire Ripley

This award recognizes the recipients for significant efforts in improving the understanding of nuclear science and technology among educators, students and the public.

The Education and Communications Award this year is being shared by Claudia Lemieux and Clair Ripley. Since 2002, Claudia has been the Director of Communications with the Canadian Nuclear Association, while Clair has been responsible for the Education Outreach Program for Atomic Energy of Canada Limited since 1993.

Last year Claudia undertook the production of the nuclear industry's first, comprehensive on-line production of an education package on all aspects of nuclear technology. The package was based upon materials first developed by Clair. Together with her extensive team, which drew upon a large number of expert individuals for drafting and review, the education modules have drawn endorsements and support from provincial education ministries across Canada, which are continuing to work to further develop the program. The new materials were released in November 2008.

Clair Ripley and Claudia Lemieux display their Education and Communications Awards.

For their efforts in producing materials for public education programs, Claudia and Clair are worthy recipients of this year's Award.

Citation

To Claudia Lemieux and Clair Ripley for their successful efforts to develop a comprehensive on-line education program.

CNS Fellowship

William G. Schneider

CNS members who are designated "Fellow of the Canadian Nuclear society" belong to a special membership category established in 1993 to denote outstanding merit. One Fellow was named in 2009

William G. Schneider is a graduate of the University of Waterloo with a Bachelor of Applied Science Degree in Mechanical Engineering.

Mr. Schneider has had a long and successful career with Babcock and Wilcox Canada Ltd., having been involved in all aspects of CANDU and other steam generators for most of his career. He is a recognized world industry leader in these areas.

As a Charter Member of the Canadian Nuclear Society, Mr. Schneider has served the Society in a variety of roles for many years, and was its President in 2004 – 2005.

Mr. Schneider was Program Chair of the Society for several

William Schneider (L) receives the certificate of Fellowship of the Canadian Nuclear Society from Jim Harvie, immediate CNS past-president.

years. Under his guidance, conferences on CANDU maintenance and steam generators have excelled and grown into major internationally recognized events. He has fostered the initiation and development of new courses and conferences of value to the nuclear industry, and has brought several important international events to Canada.

R.E. Jervis Award

Pellumb Jakupi

The R. E. Jervis Award recognizes excellence in research and development carried out by a full time graduate students in nuclear engineering or related fields who is pursuing research involving radiochemistry, radiation chemistry, chemistry in nuclear systems, or the use of nuclear research reactors in applied chemistry or chemical engineering studies. It is named after Robert Jervis a long-time professor of nuclear chemistry at the University of Toronto. The award carries a bursary of $1,000.

The R.E. Jervis Award recognizes excellence in R&D conducted by a full time graduate student of nuclear energy. The study topics required for eligibility include essentially all aspects of chemistry and chemical engineering in which ionizing radiation is a factor. Mr. Pellumb Jakupi excels in his research on crevice corrosion in nickel superalloys. The quality of his work is well recognized by national and international experts in this field.

Mr. Jakupi's specific research goal was to develop a damage function applicable to prediction of crevice corrosion of Alloy 22 in high temperature concentrated saline solutions. This damage function is intended for use in predictive models for crevice corrosion performance of this alloy over long time periods in extreme environments.

Mr. Jakupi demonstrates excellent mathematical skills as well as developed experimental talents. These abilities have prepared him well for undertaking the extremely challenging research project on which he is now engaged. His peers and his supervisors anticipate high achievements in his professional career.

(Mr. Jakupi was unable to be present for the award.)

J. S. Hewitt Team Achievement Award

The Past and Present team of the Nuclear Research Universal (NRU) Reactor

This award aims at recognizing the recipients for outstanding team achievements in the introduction or implementation of new concepts or the attainment of difficult goals in the nuclear field in Canada.

The National Research Universal (NRU) reactor started operating at AECL Chalk River Laboratories on November 3, 1957. Since then it has served as the workhorse neutron source for the Canadian nuclear industry, the broader science and engineering community, and the medical and industrial radioisotope supply sector.

The success of NRU is due to the dedication, hard work, and skill of its operations staff. NRU has operated through decades of changing policies, missions, and priorities, as well as numerous technical upgrades and reconfigurations. In addition, as a multipurpose facility, NRU sees a variety of missions that must be managed simultaneously, efficiently, and safely, making it one of the most complex and ambitious R&D facilities in Canada.

Many milestones over the years have served as testament to the ability of NRU staff to meet these challenges. A recent example was an extended period of operation at increased capacity, in order to fill a gap in medical isotope supply left by a number of unavailable global suppliers.

Citation

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

(A special ceremony will be held at the Chalk River Laboratory to enable as many past and present members of the NRU team to be present.)

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2nd Climate Change Technical Conference

by Fred Boyd

The papers and presentations at the *2nd Climate Change Technical Conference*, held at McMaster University in Hamilton, Ontario, 13 –1 5 May 2009, presented many interesting and innovative approaches for mitigating or adapting to the challenges of the changes being predicted for our climate.

CCTC 2009 was organized by the Engineering Institute of Canada, which is a society of 12 engineering organizations, including the Canadian Nuclear Society. **Eric Williams**, CNS past-president, served as chair of the Program Committee

Unlike the first CCTC held in 2006, nuclear energy was accepted as part of the answer to the climate change challenge, albeit sometimes grudgingly. The topic that elicited the most debate was "carbon capture and storage". Some argued that it was the answer to the continued burning of fossil fuel for the production of electricity or steam for industrial processes while others claimed it either would not work or would be excessively expensive.

A highlight was the presence and participation of a former Governor-General of Canada, **Edward Schreyer**, who gave the closing presentation. A lesson from history, he noted, is that we often have to make mistakes before we learn enough to deal with the problems facing us. As a recent example, he noted how quickly after the Middle East oil scare of the 1970s western societies, especially North America, forgot about the dangers of relying on an oil-based economy.

Edward Schreyer

John Gerretson

David Sanborn Scott

We still have not learned that our reserves of oil and gas are limited, he said, or that their excessive use is causing major environmental problems. While, he admitted, there are some signs of reality creeping in, nevertheless, he asserted, there is a pressing need for political will to develop and enforce policies to mitigate the climate changes already being experienced.

Another special guest was the Ontario Minister of the Environment, **John Gerretson**, who spoke after the conference dinner on the Thursday evening. He stated that the Ontario government has accepted that climate change is real and appointed a special panel under former premier David Peterson to provide recommendations. (The Panel's report will be available on the Ministry's website.) All ministries are now required to consider possible climate change and environmental effects when developing or implementing programs. The government believes in a "cap and trade" system for CO_2 emissions but the rules must be equitable and provide certainty, he stated. Ontario has a memorandum of understanding with Quebec on the subject. But this is a national issue, he asserted, and federal leadership is needed.

Also at the dinner **Dwight Willet,** corporate Vice-President of Bruce Power, a major sponsor of the conference, provided a brief review of his company. It now has over 4,000 full-time employees and there are many contractors on the site for the refurbishment of Bruce A. He noted the company's activity in Alberta and Saskatchewan. At this time, he said, they are primarily seeking public support.

The dinner was held in the Liuna Station, a beautifully restored railway station dating back to the early 20th century.

The conference was structured with 17 plenary presentations divided over three sessions, and 64 technical papers presented in parallel sessions over the three days.

David Jackson, conference chair, opened the conference and then invited **Peter George**, president of McMaster University to extend a welcome to the university and **Marc Rosen**, president of the Engineering Institute of Canada to give some introductory remarks.

John Boyd, past-president of Golder Associates and president of the International Federation of Consulting Engineers chaired the opening plenary session and gave the first presentation

Boyd titled his presentation, *The Professional Implications of Climate Change.* Engineers must work at reducing the causes of climate change and at adapting our infrastructure to accommodate the changes predicted, he said. But, he added, he questioned if engineers are adequately equipped for the challenge. We must change the engineering paradigm, he asserted. No longer are cost and schedule the primary criteria. Reduction of greenhouse gas production must be considered, he said, and there is a need for an agreed process for measuring the [expected] reduction.

Next was **David Sanborn Scott**, who spoke on a theme he has been advocating for some years, the combined use of electricity and hydrogen, for which he coined the term "hydricity". He began by saying that he was changing the title of his presentation from that published, *Reflections on the role of Services, Currencies, Hydricity, Nuclear and Renewables*, to just *Hydricity.*

The role of an energy system is to deliver energy "services", he stated, then described the relationship of: services – service technologies – currencies – harvesting technologies – source. The first two factors, the use of the energy, are often ignored in the current debate, he claimed. Electricity and hydrogen are currencies, he noted, not technologies. Electricity can be used to produce hydrogen, which can be stored, while electricity can not. Hydrogen can be used in all forms of transportation, he claimed, even aircraft. We must move to a new energy system, he urged in closing.

An overview of the global carbon cycle and its engineering challenge was presented by **David Layzell,** executive director of the Institute for Sustainable Energy, Environment and Economy (ISEEE) in an address he titled *Engineering the Carbon cycle in an Energy Hungry World.*

(The ISEEE was established by the University of Calgary in 2003 to provide leadership and coordination for developing and implementing energy and environment-related initiatives at the University.)

Layzell began by providing some data from the work of the Intergovernmental Panel on Climate Change (IPCC). Almost 10 billion tonnes of CO_2 is added annually to the earth's atmosphere by human activity, he stated, which has been estimated to cause a rise in the global temperature of 1.3 to 7 degrees C by 2100. IPCC also argues that 2º C is the limit the earth can tolerate.

USA and Canada produce twice the amount of CO_2 per GDP as other developed countries, he claimed. Status quo is NOT an option, he asserted. In his view there needs to be a charge of $200 per tonne of CO2 imposed right away. He referenced the process of carbon capture and storage, which many have proposed as a solution but stated much more research and development is needed. "There is no silver bullet", he said in closing.

Last of the introductory overview speakers was **Samuel Rosenbloom,** from the U.S. Department of Energy who spoke about the role of nuclear power in an address he titled *Energy for Life.*

Lisa Prime

David Pearson

Marc Rosen

Not only is nuclear power a "carbon free" source of electricity, he stated, it can also be used to produce ammonia for fertilizers, power desalination plants, and provide the energy to convert fossil fuel (coal) to liquid forms for transportation. Unfortunately, for those who believe in a role for nuclear energy, his presentation was not convincing.

The balance of the first morning was devoted to presentations on various approaches to mitigate the still growing production of greenhouse gases.

Hans-Holger Rogner, from the International Atomic Energy Agency, spoke about the role of nuclear energy. While acknowledging nuclear is not a "quick fix" he argued that its use for production of electricity and as an energy source for other needs, could make a substantial mitigation contribution.

Eric Beynon, from the organization Integrated CO_2 Network (ICO2N), focussed on challenge of carbon capture and storage (CCS). Considerable Canadian technology has been developed, he said, which shows that CCS is feasible and practical. There is the potential to store 100% of the CO_2 being produced in Alberta in salt formations, he claimed, but much more development work is needed. "There is a need for a long-term vision" he commented in closing.

A completely different perspective was provided by **Lisa Prime,** director of sustainability, for the Waterfront project at the City of Toronto, in her presentation *GHG Perspective on the Waterfront Revitalization Project***.** With enticing photos and drawings she provided an overview of the major project being studied in Toronto for the redevelopment of the eastern part of the city's waterfront. The very fact of her position (Director of Sustainability) demonstrates the City's desire to redevelop the area in the most sustainable way practicable. This has included consideration of many diverse aspects: transportation; soil management; social diversity; fiscal responsibility.

A "sustainability framework" has been developed, she said, that includes: green building requirements; a focus on conservation of energy; consideration of forms of transportation; extended use of internet technology.

The final speaker of the opening plenary was **David Helliwell,** of Pulse Energy, whose topic was *Using Software to Improve Energy Efficiency in Buildings.* His company has developed programs for evaluating the various ways energy is used or wasted in buildings and he spoke primarily about the application in two communities in British Columbia. Start small, he suggested, gathering "low hanging fruit". There are many aspects of buildings where energy savings can be made, he asserted. Energy efficiency should be an essential component in the planning of any development, he argued, and when buildings are built and operating energy use should be constantly measured.

The second plenary session took place at the beginning of the second day, with a focus on adaptation. **David Pearson,** of Laurentian University and chair of the Ontario Centre for Climate Impacts and Adaptation Resources, chaired the session and gave the first presentation, which he titled: *Where are we headed? – the next 100 years compared to the last 400.*

There are limits to adaptation, he said, and proceeded to show maps of the world based on predictions of the IPCC that showed that, without a marked reduction in GHG, large areas of the world would become uninhabitable by the end of this century. We do not have the socio-economic structures to deal with the problem, he asserted. To stabilize the global temperature rise at 2º C will require unprecedented technical, social, political, and ethical challenges, he added.

He argued that governments should impose changes and provide incentives, giving the example of the SO_2 problem at Sudbury of a few decades ago. Ontario, he noted, has created a Climate Change secretariat in the Cabinet Office and an Expert Panel on Climate Change Adaptation that will be issuing its first report this summer.

Barry Grear, from Australia and chair of the World federation of Engineering Organizations (WFEO), offered a global view. WFEO has eight standing committees covering a range of topics. Canada chairs the one on Engineering and the Environment. As well as natural disasters we must also plan for, and try to prevent, what he called "technical" disasters, such as large chemical spills, he said.

Presenting a view from the insurance industry, **Robert Tremblay,** from the Insurance Bureau of Canada, commented that there are more than $20 billion in claims each year in Canada. He explained

that most primary insurers off –load much of their exposure to international re-insurers. With the possible consequences of climate change he commented that there is a growing concern about the willingness of insurers to cover large disasters. At the moment their focus is on adaptation but international re-insurers are becoming interested in mitigation measures.

The City of Toronto has a new program called "Ahead of the Storm", stated **Lawson Oates,** Director, Toronto Public Works. The intent is to try to predict potential severe climate conditions, such as extreme heat wave, and plan ahead how to cope. Although a number of programs have been in place for some time they are being integrated and coordinated in face of the more extreme events now being predicted.

All of the Friday, up to the closing in early afternoon, was devoted to plenary presentations, beginning with **Thomas Garrity,** Vice-President, Siemans Power Transmission & Distribution Inc. who spoke on *Smart Technologies in Power Networks.* Electricity is the backbone of our society, he said, and the electrical grid has to become more flexible. We need to move from central control, designed for large generation units, to a system that can accommodate distributed sources such as wind and solar, he said. There are new technologies for "storing" electricity in the form of super capacity batteries, compressed air, and large magnets, he stated.

Malcolm Metcalfe, of Sempa Power, titled his presentation *A Century of Reaction Brings Crisis and Opportunity.* He argued that we should go back to D.C. electricity, as originally proposed by Edison in 1882, because it is more efficient especially for building heating. Most new loads are D.C., he claimed. When considering energy questions we should look at the "whole" picture, he said, noting that the use of low wattage lamps results in more burning of natural gas in the winter because of the loss of heat from the older lamps. There is a need to develop methods of electricity storage which, he suggested, would be worth more than the electricity itself.

From Horizons Utilities Corporation, the company installing "Smart Meters" throughout Ontario, **Frank Fabiano** described their features in a sales-like presentation, and made the usual argument that they will eventually lead to better decisions about electricity usage.

Closing off the morning session, **Alexandre Sorokine,** of Oak Ridge National Laboratories, who gave a presentation by video-conferencing on the topic *Integrative Real-time Geographic Visualization of Energy Resources.* The rapid rise of global temperature increases the probability of extreme events, he stated. Most of his presentation were satellite views of the USA with various overlays depicting population, gas pipelines, forest fires, droughts and other factors. (Unfortunately the display was poor and he spoke rapidly with a strong accent.)

The closing plenary consisted of three presentations. First was **Richard Normandin,** vice-President, National Research Council, who gave a broad overview of NRC's programs. They are focussed on the four areas highlighted in the government's Science and Technology Strategy of 2008: natural resources and energy; environmental science and technology; health and wellness; information and education technology. In the context of the conference he mentioned NRC programs on: "green" construction; hydrogen and fuel cells; nano-technology for solar cells; bio-diesel from marine algae.

He was followed by **Marc Rosen** in his role as President of the Engineering Institute of Canada, the organizers of the conference, who titled his presentation *Climate Change and Sustainable Energy: Actions and Transitions to a Lower Carbon Economy.* By "energy sustainability", he said he means providing energy services now and in the future. Some sources of energy are renewable, he noted, and others are not. (He included uranium as a non-renewable resource.) He referred to a "hydrogen economy", using hydrogen as a carrier or currency and noted we already had considerable experience with the technology. He urged a "systems" approach and life-cycle assessment of any technology.

Wrapping up the conference was former Governor-General **Edward Schreyer** as noted at the beginning of this report.

The 60 plus technical papers presented a range of information and views, with the topic of carbon capture and storage eliciting both advocates and doubters. The papers were grouped into sessions with the following headings:

Mitigation	Residential and Commercial Buildings
	Generation
	Industrial Processes
Adaptation	Hydro Power Infrastructure
	Stormwater and Flooding
	Engineering
	Water Resources
Modelling	
Education	
Impacts	
Policy and Regulation	

The conference chair was David Jackson of McMaster University. He was supported many volunteers working on: technical program; plenary program; sponsorship, etc.

It was supported by the following sponsors: Golder Associates; Bruce Power; Imperial Oil; Province of Ontario' McMaster University; Engineers Canada; Ontario Power Generation; Ouranos; Sonideft Solar; Professional Engineers Ontario; Globe and Mail; and the member societies of the EIC, including CNS.

A CD of the technical papers is available from the Engineering Institute of Canada.

Delegates gather in the grand rotunda of the LIUNA Station in Hamilton, a restored railway station, prior to the CCTC conference dinner.

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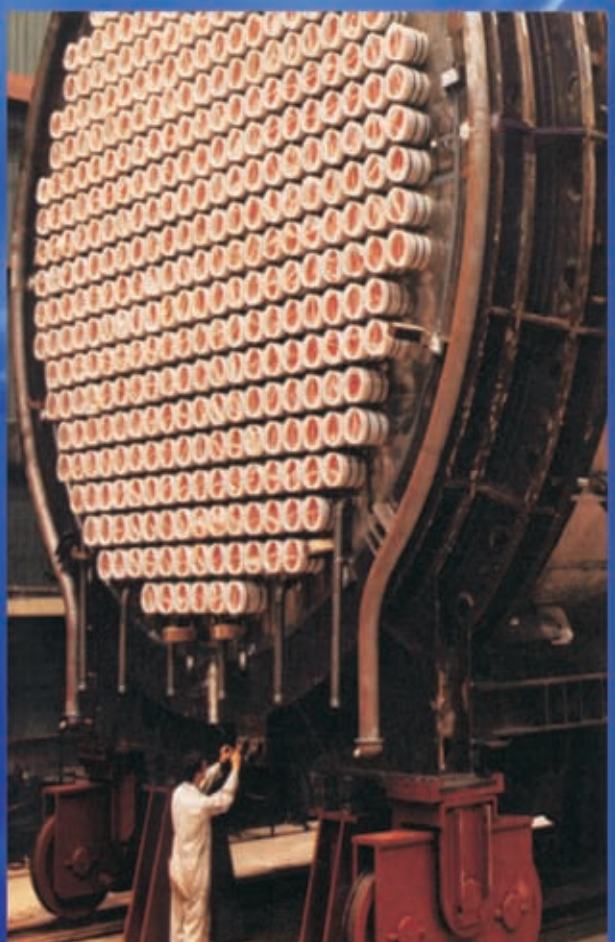

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Nuclear and Wind on the Ontario Electricity Grid

By Don Jones, P.Eng

*[**Ed. Note:** Don is a CNS Member and frequent contributor to the CNS Bulletin. His article has been edited here for length. Those wishing to read his full version can contact him directly. Opinions expressed in the article are those of the author, and not necessarily of the editor or the CNS.]*

This article is intended to show how Ontario's nuclear power plants interact with the electricity grid and how their reliability and availability will be affected by wind generation.

There are presently 16 CANDU reactors operating on the Ontario grid with a capacity of around 11,400 megawatts on a grid of about 34,000 megawatts. Although nuclear is one third of the size of the grid, it generates over 50 percent of Ontario's electricity because it is a low cost, preferred component in the Ontario system.

In 2008 nuclear and hydro combined met 77 percent of Ontario's electricity demand cleanly, with no greenhouse gas emissions, with the balance coming from coal and natural gas.

There are about 950 megawatts of nameplate wind generation connected to the grid but this is expected to increase to 5,000 megawatts over the next 20 years, or sooner, together with around 12,000 megawatts of gas-fired generation which, with oil, is presently at around 7,500 megawatts. Installed coal-fired capacity is about 6,400 megawatts but coal is to be phased-out by 2014.

The Ontario government has arbitrarily capped the installed nuclear capacity at 14,000 megawatts.

Performance

In 2008 the four CANDU units at Bruce B had an average capacity factor of 86.5 percent. The four units at Darlington had an average capacity factor of 93.9 percent and the four units at Pickering B, 71.1 percent.

Provided the demand is there even better nuclear performance can be expected in the future. Darlington's four units have now started on a three-year outage cycle and AECL's new CANFLEX fuel will result in improved operating and safety margins in all reactors, which becomes more important as pressure tubes age. However if periods of surplus generation increase (see later in article) then nuclear performance in Ontario might have to include availability factors as well as capacity factors.

Wind generator output depends on the vagaries of the wind. The Independent Electricity System Operator (IESO) assumes for planning purposes that 10 percent of the installed wind capacity is available at the time of the weekday peak. Of course, it could be zero percent. If the annual capacity factor was 20 percent wind would need 5,000 megawatts of nameplate capacity to give 1,000 megawatts of "firm" generation.

Nuclear plant operating modes

When supplying power to the Ontario grid the CANDU units have two operating modes.

(a) Reactor-following-turbine plant operating mode

If CANDU and the new ACR-1000 (proposed for Ontario new build) units are operating in reactor-following-turbine mode they can contribute to grid frequency stability. The steam generator pressure, which will change due to differences in reactor output and turbine-generator output, is kept at its setpoint by changing the reactor power setpoint, using the reactor regulating system, to accommodate changing turbine steam demands in response to grid conditions. Any difference between generation and load on the grid shows up as a grid frequency deviation from the nominal 60 Hz. If a unit is operating at 97.5 percent of full power it can provide +/- 2.5 percent power variation automatically by turbine governor action.

For an ACR-1000 this translates to around plus or minus 25 megawatts and means that if grid frequency departs from the nominal 60 Hz a unit can increase or decrease power up to 25 megawatts to resist the frequency change on the grid. The more units contributing to this grid stabilization the less the power variation will be on each unit.

Automatic generation control (AGC) service corrects the minute-to-minute variations in generation and load. The current AGC service requirement from the IESO is for at least plus or minus 100 megawatts at a ramp rate of 50 megawatts per minute.

The CANDU units are not presently used for AGC service. At present AGC uses mostly Hydro. Wind powered generators would result in more perturbations to the grid causing larger and more frequent correcting action by all the units on the grid, including nuclear.

(b) Turbine-following-reactor plant operating mode

If the nuclear unit is operating in turbine-following-reactor mode it makes no contribution to grid stability. In this mode of operation the steam generator pressure is controlled at its setpoint by operation of the turbine governor valve when the reactor power setpoint is changed for any reason.

In Ontario the CANDU units are operating in turbine-following-reactor mode, preferred by operators Bruce Power and Ontario Power Generation, and at the maximum allowable power, normally 100%. This mode gives more stable reactor operation and increases the probability of the unit remaining connected to the grid during major disturbances, as well, incidentally, as generating more electricity and more income. However, in a future with coal and eventually unsustainable natural gas phased out the nuclear stations would have to operate in reactor-following-turbine mode to help stabilize the grid, so in this case wind would be a hindrance.

1 Nameplate is the total capacity at the design wind speed, but the wind on average is much less than this; the average output from wind (or its capacity factor) is typically less than 20%.

Dispatchable load-following

In order to keep the designated plant that is on AGC service in its desired operating range, particularly during the difficult morning ramp-up and the evening ramp-down, other selected units on the grid will be dispatched at frequent intervals to power up or power down to balance the grid by matching generation to energy demand. This would be the job for load-following hydro (very flexible), coal (flexible, low minimum load level) or gas-fired units (less flexible, high minimum load level). If wind is ramping down in opposition to a demand which is ramping up it will make the job of balancing the grid more difficult.

Dispatches take into account the technical constraints and economics of the unit being dispatched and are sent at five minute intervals. Lower priced generation will be used ahead of higher priced generation subject to transmission restraints or other reliability related considerations. Although the nuclear units operate baseload the IESO regards them as dispatchable and in the future, with coal and eventually natural gas phased out, load-following nuclear and hydro would have to respond to these dispatches.

For example, the new ACR-1000 uses steam bypass in combination with control of reactor power to provide flexible load-following operation and very likely AGC. The steam bypass system on the current CANDU units were not designed for daily dispatchable load-following so they would respond slower to dispatch. However, if necessary, changes to the reactor power setpoint could be made that would follow up on the fast initial response of the hydro units to the dispatch.

For current nuclear units with aged pressure tubes there needs to be enough safety margin available for a shallow power reduction to be made at high power without exceeding fuel bundle power limits. Raising reactor power in a CANDU takes more time than reducing reactor power if it were necessary to withdraw adjusters after the power reduction and this may affect dispatch response.

Surplus baseload generation (SBG) is an over generation condition that occurs when Ontario's electricity production from baseload facilities such as nuclear, must-run hydro-electric units (must run and not spill for regulatory reasons) and non-dispatchable wind is greater than market demand. In the future, with 14,000 megawatts of nuclear online, more conservation and much more wind powered generation, the frequency of SBG events will dramatically increase and so will the number of times that nuclear plants will be asked to load-follow or to reduce power sufficiently enough that hydro can respond to load-following dispatches. This will increase wear and tear on the nuclear units.

At the present time the grid operator, the IESO, only considers the curtailment of wind generation when all market mechanisms are exhausted, including nuclear shutdown. Now the grid operator is proposing that curtailment of wind generation is considered if the nuclear units can mitigate the SBG situation only by taking the risk of not being available in future hours when they will be needed, for example, a deep reactor power reduction or a shutdown. This dispatch priority for SBG events is a continuing major concern of the IESO and it is likely the future will see a juggling of dispatch between nuclear, wind and spilling water.

Increasing amounts of wind generation will make the job of balancing the grid even more difficult especially during the daily periods of major load changes. If the wind generation displaces gas-fired generation the nuclear units would have to respond to load-following dispatches.

Future climate change may affect the capacity of hydro-electric facilities putting more pressure on the nuclear plants. Even now some hydro plants may not be available all the time, there are seasonal fluctuations in water supply, there may be local, provincial or international agreements on water management, or water is being kept in storage for load following or operating reserve.

The load-following and operating reserve capability of the hydro plants will become even more valuable after the phase-out of flexible coal-fired generation and should not be squandered to support wind.

Load-cycling

Some generators on the grid have to accommodate daily load-cycling since demands are low during the night and high during the day. These are the hydro, coal and gas fuelled plants. The CANDU plants operate baseload at full power for economic reasons although in the past some domestic units (Bruce B) and off-shore (CANDU 6) units did accumulate considerable good experience with load-cycling, with some deep power reductions, but not on a continuous daily basis.

Analytical studies based on results of in-reactor testing at the Chalk River Laboratories showed that the reactor fuel could withstand daily and weekly load-cycling. However, this confidence may not necessarily apply to frequent dispatchable load-following duty even though the new CANFLEX fuel will provide improved margin to failure over the present fuel. It should be remembered that all CANDUs have failed fuel detection and location systems and failed fuel can be replaced while the reactor is at full power. On-line refuelling also results in consistent manoeuvring performance since the amount of excess reactivity does not change much with time.

All CANDUs were designed to be capable of quickly reducing power to 60 percent of full power, holding at reduced power, and then returning more slowly to full power, using their adjuster rods (Bruce A excepted). The specification for the new ACR-1000s states that they are designed to rapidly reduce power from 100 percent steady state down to 75 percent full power overnight and periodically down to 60 percent or even 50 percent on weekends. Use of low-enriched fuel and light water coolant in the ACR-1000 has resulted in a lower xenon load following a power reduction compared to CANDU and this simplifies reactor operation, making the ACR-1000 inherently more responsive so the adjuster rods found in current CANDUs are not necessary.

Bruce B had three weeks of day/night load-cycling in the early spring of this year to help the grid operator cope with an extended SBG situation. Each unit saw 300 megawatt load changes occurring in less than two hours with output reduced to about 64 percent of current maximum electrical output, using steam bypass. The ACR-1000 and the CANDU electrical output can be reduced even more, to around 6 percent full power, just enough to supply the plant's auxiliary services load, with the

reactor held at around 60% full power and steam bypassed around the turbine to the condenser. This mode is normally used if the grid goes down (blackout) since the reactor can remain at 60 percent full power indefinitely until the grid is re-established. In this so called "poison prevent" mode the already hot turbine can be quickly brought up to 60 percent power by gradually closing the steam bypass valves to load the turbine and then the slower return to 100 percent power output can begin.

Flexibility

The 2005 December 9 Ontario Power Authority (OPA) Supply Mix Advice Report to the Minister of Energy revealed many references to perceived nuclear operational inflexibility. The IESO still has this pessimistic outlook on nuclear flexibility but at the same time is promoting more wind which will cause even more periods of excess supply during periods of low demand causing the low cost nuclear units to reduce power or load-follow to accommodate high cost wind.

Much more recently the IESO has again complained about nuclear manoeuvrability. In its draft "Dispatch Priority" of 2009 Feb. 4 and referring to SBG it states, "Nuclear generation is limited in its manoeuvrability. Often times when asked to move, the nuclear generator will agree for technical reasons, to a specific MW amount which may be much greater than what they were asked to move. For example, the IESO may request a nuclear unit to move 80 MW down. Due to equipment limitations, the nuclear unit may agree to move down but will have to move by 300 MW."

It is not clear if the IESO is saying that this is a fault of Ontario's "nuclear" in general or of a specific nuclear station that has manoeuvring restrictions. It reads like it could be the result of pressure tube ageing eating into the safety margins so that fuel bundle power limits would be exceeded if adjusters were pulled at relatively high power after a shallow power reduction in response to a SBG dispatch. If so, this would be alleviated by the new fuel and/or refurbishment.

To avoid changing reactor power Bruce Power's nuclear units currently respond to occasional SBG dispatches by implementing a tightly choreographed turbine steam bypass procedure to reduce unit electrical output. Of course using steam bypass to reduce electrical output is not as efficient as reducing reactor power and it also causes wear and tear to the bypass system and eats into thermal fatigue life. There are also thermal emission constraints with the temperature of the cooling water returned to the lake. Darlington, as designed, should be able to respond to a SBG dispatch by reducing reactor power, with no need for steam bypass unless a deep electrical power reduction is required and a return to full power could be expected within a short time period.

CANDU nuclear steam plant is designed to manoeuvre in the upward direction at 4 percent of actual power per second when at powers of between zero and 25 percent of full power and at 1 percent of full power per second when at powers of between 25 and 80 percent of full power. Above 80 percent of full power core boiling restricts the upward manoeuvring rate to 0.15 percent of full power per second. The plant can also quickly respond to a 5 percent step increase in output demand, provided unit is operating at least 5 percent below full power. All this assumes no operational constraints that would limit power increases. The plant power manoeuvring rate is limited by the turbine rather than by the reactor to between 5 and 10 percent of full power per minute but in practice much lower manoeuvring rates are used. Although this information applies specifically to the CANDU 6 it should also apply to most of Ontario's CANDUs as well.

In the downward direction there is no limit to the rate of station electrical power reduction. The combination of steam bypass and reactor power reduction allows a sudden electrical output reduction of any magnitude, even 100 percent load rejection caused by loss-of-line, to be tolerated without a turbine or reactor trip. The reduced reactor power level is normally limited to 60 percent full power or more (i.e. a 40 percent power reduction), so called "poison prevent" level, to prevent excessive xenon transients. A return to full power can be achieved in less than 3 hours depending on the amount and duration of the power reduction and other conditions, which allows for load-cycling.

The future

The North American Electric Reliability Corporation (NERC) released it's Special Report, "Accommodating High Levels of Variable Generation", on 2009 April 16 describing what needs to be done in the future to integrate wind into the grid, including the provision of sufficient flexible support generation.

Wind will be a hindrance, and not a help, to nuclear operation as well as to grid reliability on a nuclear/hydro grid. Running nuclear and baseload hydro units that have high fixed cost and low operating cost at reduced power and varying outputs to support expensive, intermittent and varying wind power makes little economic sense and there are no environmental benefits to having wind on a clean nuclear/hydro grid. High wind generation coupled with low grid demand, a major concern of the grid operator, will put more unnecessary manoeuvring demands on the nuclear units and put the grid at risk.

The 2006 October "Ontario Wind Integration Study" by General Electric International Inc. for the IESO and the OPA, like all similar studies, looked at a grid with significant flexible generation from hydro and from coal and natural gas-fired units to support wind, when it is blowing and when it is not. In the future the Ontario grid may not have coal or gas and wind could impact on the reliable and economical operation of the nuclear stations and hence the reliability of the grid. Even now, with gas-fired generation and a small amount of wind, periods of SBG result in nuclear units being powered down so even higher penetrations of wind, with nameplate capacity of around 5,000 megawatts, would make these events more frequent. As the wind generation displaces the more flexible generation the nuclear units would have to be able to respond to load-following dispatches or alternatively nuclear could attempt to reduce electrical output substantially, using turbine steam bypass if necessary, to allow hydro to load-follow.

The future of nuclear load-cycling and even shutdown arrived in the early spring when Bruce B had three weeks of day/night load-cycling with mainly 300 megawatt power reductions on the units to help the IESO cope with a very extended SBG situa-

tion. Spring is normally a low demand season but this year it coincided with the downturn in the economy. To avoid having the nuclear units load-follow they took big power reductions overnight so that the hydro units could take care of the overnight load-following dispatches since, being spring, there was lots of hydro. Bruce B had 66 day/night load-cycles over a three week period. Wind was averaging several hundred megawatts over the SBG period. A few thousand more megawatts of wind into the grid (if it were there and injected) might have put other nuclear units into a low power mode overnight or even shutdown making them unavailable for up to three days, which would have resulted in more coal being burned during the higher day time demand. Even so, for long SBG periods in the future nuclear unit shutdowns may be a possibility.

Bruce Power states that SBG is its "number one operational concern" and that "manoeuvring nuclear units represents a significant reliability risk to the province". Yet despite Bruce Power admitting that wind will increase SBG events its CEO earlier this year said, when promoting the wind farm it owns, that "wind and nuclear generation naturally complement one another". Bruce Power owns Huron Wind, a 9 megawatt wind farm in Bruce County.

Summary

The design of the CANDUs at each of Ontario's five nuclear generating stations evolved over time from Pickering A to Darlington and they have different operating characteristics and limitations. They are solid baseload performers and although they were not designed to quickly respond to frequent load-following dispatches, like the new ACR-1000, they should be able to respond to less urgent and less frequent dispatches. CANDUs have the capability to load-cycle by quickly reducing power to 60 percent of full power and then returning more slowly to full power, without using steam bypass. Past operating experience and fuel studies show that this is achievable on a daily basis, though possibly less frequently if steam bypass is involved. For load-following and load-cycling the operating limits are set by fuel safety margin, fuel fatigue life, and the thermal fatigue life of the steam bypass system.

Wind will increase the times the nuclear units will be exposed to load-cycling, or even load-following and shutdown, causing them unnecessary wear and tear and decreasing grid reliability. Wind is a negative influence to the Ontario grid and its nuclear units. Natural gas-fired plants are supposed to support the present installed wind generation but even today periods of low demand have resulted in the manoeuvring of nuclear units and this will become more frequent with more wind and even more so in the future when the gas buffer disappears.

Nuclear is capable of supplying base, intermediate and peak loads. Nuclear hydrogen produced overnight would power turbines/fuel cells to help satisfy the day time load including peak loads, reducing the demand on hydro.

Recommendations

The nuclear industry and the IESO/OPA should take a close look at the co-existence of nuclear, hydro and wind on the future Ontario power grid. More wind, even with natural gas available, will result in unnecessary wear and tear on the valuable nuclear units giving lower unit availability and consequently lower grid reliability. The generation of hydrogen by nuclear units during periods of low demand could smooth out the load on them and provide fuel for the afternoon peak demands, and should be pursued.

Plant and grid operators should get together to clarify the capabilities and limitations of specific current and refurbished CANDUs to load-follow and load-cycle.

The Ontario Energy Board should take a critical look at the viability of grid wind power in Ontario together with its reliance on unsustainable natural gas-fired electrical generation.

Power Reactor Safety Comparison – A Limited Review

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[Ed. Note: This paper was presented at the 30th Annual Conference of the CNS.]

Abstract

A large amount of attention has been paid to avoiding positive coolant void reactivity in LWR reactors. This can be justified due to specific accident events that could lead to severe consequences. Somewhat less attention has been paid to other accident sequences that can lead to positive reactivity addition. Other designs, for example the CANDU-PHWR, exhibit positive coolant void reactivity but include both inherent and engineered systems that compensate for this undesirable characteristic. This paper represents the beginning of a long-term process intended to enable a balanced and fair comparison of the real safety of all reactor types.

1. Introduction

The formal report that led to the production of this paper was issued for public distribution in 2009 [1]. This paper highlights only two of the several points brought forward in that report; a companion paper in this conference examines some other aspects of the report's findings.

This paper has two objectives. The first is to place the Postulated Initiating Event (PIE) [2] identified as Large Loss-of-Coolant into proper context with similar accident events in both pressurized water reactors and boiling water reactors. The second objective is to initiate a logical process for inter-comparison of the safety of various reactor types, within the context of the International Convention on Nuclear Safety [3].

There are many possible definitions of a "safe" reactor. For reactors employing solid oxide fuel, the most elementary demonstration of safety is the one in which it can be proven that all (or almost all) fission products remain within the fuel sheath following all PIE. Implicit in this requirement is that the fuel pellets should never reach the molten state. Additional limits are placed on fuel enthalpy if the energy is added very rapidly. Of course, this condition – sufficient fuel cooling -- must be maintained in the long term following any accident.

In the early days of uranium energy utilization there was no need for comparison of safety on an absolute basis. Regulation was purely a national matter, and local judgments of sufficient safety were independent of one another. This situation has changed. Several different reactor concepts are, or soon will become, part of the generation mix in the world. Naturally there is a tendency for each commercially-driven entity to claim that the plant they build is "safer" than its competitors' products. There is still no common yardstick by which safety can be measured.

This Convention on Nuclear Safety was adopted in 1994 with the objective of normalizing and "equalizing" in some fashion the safety requirements of various nations. Its aim is to legally commit participating States operating land-based nuclear power plants to maintain a high level of safety by setting international benchmarks to which States would subscribe. Four review meetings have been held. However, there is still no agreed means for comparing the absolute risk from operation of one power plant type with the operating risk of any other nuclear plant.

Probabilistic risk analysis is sometimes considered for safety inter-comparison. This method is extremely valuable in most situations, especially for judging the relative reliability of plant components and systems within a single plant design. The method is limited, however, in some very important aspects. The first is the question of completeness; that is, the question as to whether or not all important postulated initiating events (PIE) have been considered. The second limitation arises from the nature of some accident sequences. Such sequences may lead (as they have in past accidents) to extreme-value consequences, even at a relatively high frequency of occurrence. This situation arises because of the basic fact of operation of nuclear plants they are complex systems operated by humans.

Safe operation of any nuclear station depends most heavily on the performance of the operating staff. At the same time, even a high skilled group of operators (e.g. the space shuttle team) can, through errors of commission and omission, induce system failures in so many different ways and combinations that construction of a comprehensive model of the process is not practical.

2. Reactivity-Initiated Accidents

Reactivity-initiated accidents (RIA) have the largest potential for leading to large radioactive material releases because of their potential for adding reactivity up to and beyond the value of the delayed-neutron fraction, with consequent rapid energy addition. If the fuel of a solid-fueled reactor approaches or exceeds its molten state, most fission products are released and have the potential for causing damage at a distance.

With the exception of the CANDU design, RIA events happen too quickly to be controlled by engineered shutdown systems. As a result, many reactor designs must depend on the inherent mechanism of Doppler resonance broadening with increasing fuel enthalpy, to achieve timely reversal of the increasing total reactivity. The Doppler feedback phenomenon is very effective in this role, with one important reservation – the negative reactivity introduced by Doppler feedback must eventually

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be fully compensated by other systems (generally, engineered systems) before the reactor can be "rendered safe" [2].

This scope of this study was too limited to provide for complete analysis of even one RIA event in a power reactor, much less to carry out a comparative analysis of several cases. Even the presentation of results for one event is far beyond the space limitation of this paper. The approach taken in this work was to examine only the first few seconds of the event -- during the RIA power pulse -- and to examine the fuel enthalpy and total reactivity conditions during this time. Furthermore, the power pulses examined were taken from earlier analyses by others, mostly in the context of power reactor licensing applications.

The rationale for beginning the comparison of relative safety of different reactor types with this particular parameter is the fact that essentially all of the dangerous radioisotopes are normally trapped in the fuel pellet, coupled with the fact that the pellet is the innermost effective barrier in the defence in depth design concept.

Tests of uranium dioxide fuel elements provide a quantitative measure of two important parameters. First, they indicate the maximum incremental enthalpy insertion to a fuel pellet prior to partial melting. The second useful item of information is the limit on rate and quantity of energy addition prior to fuel fragmentation. Subsequent analysis of RIA events can use these data as indicators of the onset of major release of fission products.

The prompt critical transition in a reactor with substantial negative reactivity feedback from Doppler resonance broadening determines the maximum total reactivity that will be reached in a transient because the negative feedback (proportional to the energy integral) is usually faster than the original positive reactivity addition rate. There is, of course, a limit to total Doppler feedback because fuel enthalpy limits are quickly reached in these cases. While the CANDU reactor has only a small negative Doppler coefficient, the rate of increase of reactor power is limited by its relatively long prompt neutron lifetime (about 40 times longer than that in a PWR). As a result the enthalpy rise rate is much slower in this reactor in the prompt critical range. It is slow enough, in fact, that engineered shutdown mechanisms become practical means for reducing the total reactivity.

3. The International Convention on Nuclear Safety

The apparent need to improve CANDU Large LOCA safety margins was raised in the Third Review Meeting of the International Convention on Nuclear Safety in Vienna in 2005. The known positive reactivity change following coolant voiding in CANDU reactors has been discussed at Convention review meetings and in other international forums for several years. Canada reaffirmed, at the 3rd review meeting, that NPPs in Canada meet all international safety requirements. The general perception that a positive void reactivity coefficient is a serious inherent weakness of any reactor design likely has contributed to the fact that the subject of CANDU Large LOCA safety margins has been raised during successive review meetings.

By the same token, an important inherent strength of the CANDU design, namely, its relatively long neutron lifetime, has not been sufficiently well understood by the international community. Because each reactor type has a combination of beneficial and detrimental characteristics, and because each design incorporates engineered design features to compensate for these limitations, it is important to review this particular area in a balanced and factual manner when attempting inter-comparison of the overall safety of different reactor types.

While Canada's statement that CANDU reactors already meet international design and safety standards has not been called into question explicitly by parties to the Convention, a question on the need to improve one of the safety requirements (Large LOCA margins) has been raised. Subsequent to the 3rd Review Meeting, Canada made a commitment in the follow-up anniversary report to "continue the program to improve Large LOCA safety margins" through two parallel approaches, viz., plant design changes and safety analysis tools/methodology improvements. The latter, in particular, includes development of best-estimate and risk-informed methodologies consistent with the CNSC Executive's strategic direction towards a more risk-informed approach to resolving outstanding safety issues. Progress on this commitment was reported by Canada at the 4th Review Meeting in April, 2008. Discussion of the issue has been prominent in other international forums, such as the recent CANDU Owners Group TCM in Romania. [4].

Resolution of the Large LOCA margins issue principally relates to Article 6 (Existing Nuclear Installations) and Article 14 (Assessment and Verification of Safety) of the International Convention. Implicit in Article 6 of the Convention is the need to "upgrade" the safety of each existing plant when necessary in the context of the Convention. This sentence implies the need for comparison of a plant's level of safety against an agreed set of standards such as those developed by the IAEA. The IAEA documents are intended to be solid consensus standards based on common worldwide approaches.

This paper undertakes a simple analysis of only one aspect of this comparison – the fuel energy input during the first few seconds of those RIA transients unique to each reactor type. This first step is essential to consideration of safety margins, because to seriously consider safety margins one must first define what is meant by the term; that is, to answer the question "Margins to what limit?" Both probability and consequence of failure (i.e. both frequency of occurrence and the consequence of exceeding the limit) form part of this answer. Provided the particular reactor being considered exhibits safety performance similar to other reactors existing at the time the Convention entered into force, it is reasonable to conclude that no "upgrade" is then required within the context of the Convention.

Canada is aligning with international approaches [e.g. 5, 6] in these areas (Probabilistic Risk Assessment, Periodic Safety Review, and Risk-Informed Decision Making). With respect to Large LOCA issues, better refinement of the safety margins and more accurate value-impact assessments are expected as we align with the international approaches. Although improvements have been made, and although the overall risk remains small when all aspects of improved knowledge are considered, further work is in progress to examine potential improvements to Large LOCA

safety margins through the parallel approaches of plant design change (specifically new fuel and safety system designs), and safety analysis/methodology development.

In the international context resolution of the issue of Large LOCA safety margins will rest on the fact that existing CANDU reactors are not only adequately safe when compared with international standards, but that all "reasonably practical improvements are made" to increase safety margins.

This paper addresses the first of these issues, and the companion paper in this session presents the current approach to the second issue.

4. Margins to Safety Limits

Both the frequency of occurrence of close approach to a specific defined limit and the consequence of exceeding that limit are important to a discussion of safety margins.

Knowing an approximate frequency of occurrence is important because of the working definition of safety as the inverse of risk. Risk is in turn defined according to the normal practice of insurance actuaries and nuclear safety specialists, as the product of frequency and consequence.

Consequence is easily defined as the result of exceeding a given safety limit. However, in any deterministic analysis the difficulty lies in finding ways in which the defined limit might be exceeded. In this analysis, the general approach is to examine all the known means through which the calculated consequence is controlled; that is, how is the parameter in question maintained below the limit? For example, the means may be via inherent reactor characteristics, by action of engineered systems, or by adequate depth of shutdown.

Then we find the most important "next failure" that involves postulated inaction of the controlling mechanism. Knowledge of the conditional probability of the "next failure" is, of course, essential to this process.

5. Case Study Framework

Given the limitations in the scope of work, our choice was to select published information from sources mainly associated with license applications of the various reactor types. It is realized that this choice introduces uncertainties in modeling such as the degree of conservatism forced on the analyst by regulatory rules; or more specifically, the differences in these rules between various jurisdictions. From previous experience it was decided that this uncertainty could be neglected because of the relatively uniform conservative assumptions required among the world regulatory agencies. Some specific exceptions are noted in the following descriptions.

Selection of specific cases began from the first postulate of some malfunction that could lead to a substantial positive reactivity insertion. A search of the literature revealed a limited number of well-documented cases. It was decided to choose cases describing these events in reactors that have already been constructed and licensed, or that are now in the late stages of preparation for construction.

The primary correlating parameter of the various RIA cases is fuel enthalpy. In both LWR and CANDU reactor designs, accidents that result in a rapid positive reactivity addition terminated by shutdown are characterized by an "integrated energy addition" to the fuel during the power transient. This power transient is typically no more than about 2 seconds in duration, and since fuel cooling is negligible during this time, the energy addition is well approximated by the time-integral of the fuel power transient.

Since the power decreases very rapidly after shutdown occurs, the total fuel energy (or enthalpy) reaches a maximum value within a few seconds. This result is expressed as a "peak radial average fuel enthalpy" as this is the value that has been shown to determine the degree of fuel damage in numerous RIA tests performed on LWR, VVER and CANDU-type fuels in various research reactors. For ease, the "peak radial average fuel enthalpy" will be referred to henceforth as "peak enthalpy".

5.1 Specific Comparison Cases

The reader is reminded that the following comparison has only a narrow and specific scope and that it makes no claim for or against the overall safety of any of these power plant designs. All of the postulated accident cases discussed in this Section incorporate engineered systems (shutdown, containment, and long-term heat removal) to render the plant safe. All of the plants discussed, and many other plants of the same type or class, have been judged to be adequately safe by regulatory authorities in a number of countries. Furthermore, extensive worldwide operating experience with the current generation of these plant designs has fully vindicated this regulatory judgment.

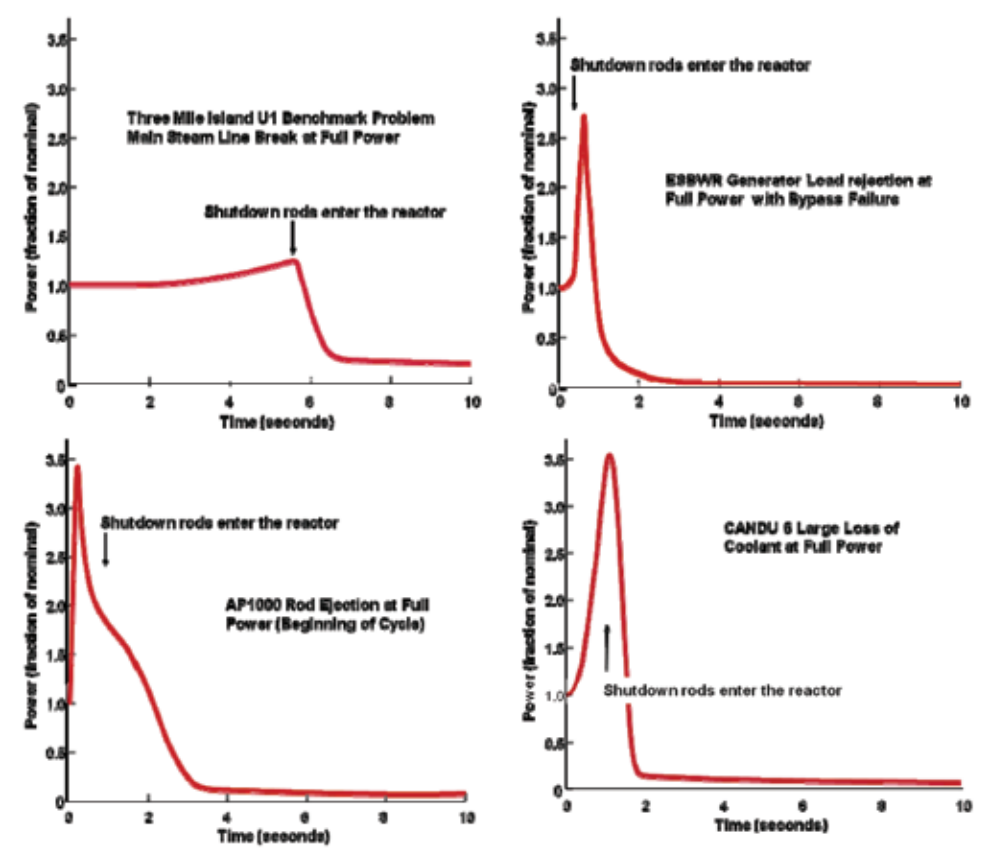
The selection of extreme cases presented tends to hide a very important fact. This fact is that the accidents described here are extremely unlikely, and the assumptions and methods leading to the behaviours described here are deliberately arranged so that the event consequences are maximized, or at least made more damaging than would be expected in the real world.

Short-term power histories for each of these cases are shown in the multi-part Figure below.

5.1.1 TMI-1 main steam line break (MSLB-FP)

The TMI MSLB event was chosen for comparison because the event begins with the PIE 'rupture of a large coolant pipe'. The information for this case is taken from an OECD/NEA benchmark problem solved at a number of laboratories. [7] Flashing on the secondary side of the broken steam generator results in rapid cooling of the primary coolant, the rate and magnitude depending on assumed closure or non-closure of isolation valves.

There is a time delay of a few seconds before cold primary water enters the reactor, during which time reactor trip signals are issued. Shutdown rods begin to enter the core 7.5 seconds after the event, at which time the peak total reactivity is about +1 mk and peak power is about 1.25 times full power. Peak enthalpy does not change significantly; it remains at approximately 450 J/g. Shutdown rod insertion decreases the reactivity by about -40 mk at 10 seconds post-break.



Total positive reactivity added (from primary side cooling and fuel cooling) is about +15 mk at 10 seconds after the event, and about +40 mk after 50 seconds. Total reactivity rises slowly and returns to near zero approximately 50 seconds after the pipe break. The overall result is sensitive to reliable and timely control rod action. Reactor power would rise rapidly if rod insertion were appreciably delayed. Negative Doppler feedback would effectively limit the resulting power transient. Maintaining the reactor in a subcritical state during long term cool-down likely would require action of a secondary shutdown system.

5.1.2 ESBWR generator trip with failure of steam bypass (GTFSB-FP)

This event was chosen because the transient is very fast and because control response must be equally fast in order to prevent insertion of a large positive reactivity. An anticipated transient (generator trip) precedes the ESBWR PIE. The positive reactivity addition is caused by collapse of steam bubbles resulting from the transient overpressure. Timing of the overpressure is determined by the travel time of the pressurization waves from the closing valve to the reactor core. Turbine stop valve closure is initiated at time zero by the generator trip signal, and is completed after 0.1 seconds.

The PIE begins with total failure of turbine bypass valves to operate in response to the generator trip signal. A reactor trip signal is initiated at 0.15 seconds and the rods begin to enter the reactor at 0.4 seconds. Peak reactor power of 2.5 times full power is reached at 0.8 seconds. Rods are fully inserted after 3 seconds, thus rendering the reactor safe (provided that long term fuel heat removal is available). Void collapse results in a reactivity increase of +5.53 mk during the first 0.6 seconds. Control response returns the total reactivity to about zero after 0.9 seconds. Reactor power rises very rapidly as the turbine stop valve closes, and then decreases. Doppler feedback reactivity is slightly positive beyond 5 seconds due to cooling of the fuel. Control response acts very rapidly to limit the peak total reactivity to 2.8 mk at 0.6 seconds, and continues to add negative reactivity until it reaches –166 mk after 3.5 seconds. Peak fuel enthalpy is 395 J/g. Positive reactivity (from void collapse) is about 37 mk at 8 seconds following the generator trip.

5.1.3 AP1000 cluster control assembly ejection, full power start of cycle (RCCA-FPBOC)

This event was analyzed by the designer. Results are published on the website of the US Nuclear Regulatory Commission [9]. As is usual in licensing analyses, a number of conservative assumptions are made to give assurance that an actual rod ejection event would be less severe than the one analyzed. The frequency of this PIE is judged to be extremely low.

Control assembly ejection is a very fast event. Peak total reactivity is approximately 3.5 mk at 0.14 seconds under full power beginning of cycle conditions (delayed neutron fraction 4.9 mk). The resulting power pulse is reversed by Doppler feedback and then shutdown rod insertion begins at 0.93 seconds. The hottest fuel experiences less than 10 percent melting. Peak fuel enthalpy at the hot spot is 758 Joules/g.

A second analysis was carried out for AP1000 at initial conditions typical of zero reactor power at the end of an operating cycle. The main difference in this case relative to the full power case is that the ejected rod has a larger positive reactivity, as calculated for the maximum allowed rod insertion at zero power level. The control rod positive reactivity in this case is considerably larger than the delayed neutron fraction. Of course, the fuel is cooler than it is at full power because the unit is at zero power in this case.

The case illustrates the effect of the short prompt neutron lifetime of the PWR, and the resulting mitigation of the power increase by the Doppler feedback. Reactor power rises extremely fast, through many decades in a small fraction of one second. Peak power of approximately 15 times full power is reached at 0.27 seconds. Shutdown rods begin to enter the reactor at 1.13 seconds. The peak total reactivity is estimated to be approximately equal to the delayed neutron fraction of 4.4 mk under these conditions. The peak fuel temperature is 1795 C at about 2.9 seconds. Peak fuel enthalpy at the end of the transient is 490 Joules/gram, below the expected fuel failure threshold.

5.1.4 CANDU 6 large loss of coolant (LLOCA-FP)

The CANDU Large LOCA case was chosen because the event begins with the PIE 'rupture of a large coolant pipe'. This particular case depicts the relative peak bundle power following a 100% break in a coolant pump suction pipe. At the same time analytical models of the transient thermal-hydraulics of the system are chosen to be conservative in the sense of producing the maximum calculated coolant voiding effects.

Within 2 seconds following a sudden break in a large primary circuit pipe, steam is produced in the reactor core and liquid coolant is ejected from both ends of the fuel channels. Trip signals (high neutron flux and high rate of change of the logarithm of the flux) are issued about 400 milliseconds following the event, and rods begin to enter the core at 0.9 seconds. Peak power of 3.5 times full power is reached at 1.16 seconds, after which either SDS1 or SDS2 decreases the reactivity to -69 mk or more after 2 seconds. The peak total reactivity is +4.3 mk at 0.9 second (compared with the delayed neutron fraction of 5.2 mk) and the peak enthalpy is 638.5 J/g; Doppler feedback is small and negative. The total positive reactivity addition is about +15 mk at 10 seconds after the event. Final shutdown is reached at 2 seconds after the event, so that (with assistance from other engineered safety actions such as emergency fuel cooling) the reactor is rendered safe.

5.2 Hypothesized "Next Failure" Consequences

The experience from historical extreme events [10] indicates that improbable combinations are likely to have "fat tails"; that is, they show non-Gaussian probability distribution on the wings. Reactor accident analysis involves, by and large, examination of the consequences of such extreme events, without close examination of their associated probability.

The resilience of predicted limit-consequences of any accident sequence can be tested by postulating a series of "next failures" and estimating their consequences. This is sometimes referred to as testing "cliff-edge" effects in accident analysis. This method was applied by the AECB some years ago in the context of CANDU licensing proceedings.

Applying this idea to the cases selected here leads to the following observations.

Control rod ejection is an unlikely event in a properly maintained PWR. However, the severely degraded condition of the Davis-Besse vessel head brought the possibility of such an event into sharp focus and led to extensive inspection and correcting actions at several similar plants around the world. With reference to section 5.1.1, the most immediate "next failure" might involve the ejection of more than one rod cluster, leading to positive reactivity addition well in excess of the delayed neutron fraction.

Rod ejection from zero power shows similar behaviour to the full power case, except for its faster power rise and consequent possibility of fuel shattering.

Main steam line break in a PWR is well controlled, provided one assumes successful closing of isolation valves in the unbroken steam lines, so that the speed and magnitude of primary water cooling is limited. The "next failure" might involve the valves remaining open, or might arise from delay or failure of borated water injection within the next few seconds. Either of these events would result in a super-prompt-critical transient with substantial fuel temperature rise and negative Doppler feedback. Long term fuel cooldown as well as sustained high boron concentrated in the core water would be essential to render the reactor safe.

A major pipe break in CANDU6, assumed to occur instantaneously at time zero, is well controlled by either shutdown rods or by liquid poison injection into the moderator. The "next failure" may be complete failure of one shutdown system. In such an event, the independent second shutdown system would operate, leading to rapid shutdown. Long term cooling by ECCS water would render the reactor safe, especially because the light water emergency coolant acts effectively as yet another source of negative reactivity. Even in the event of complete failure of the ECCS, rejection of heat to the moderator water would prevent fuel melting. In CANDU 6, a steam line break would produce a negative reactivity transient. In fact, the resultant cooling of primary water has a beneficial effect on safety in case of a large LOCA event, as it aids the injection of ECCS water.

Failure of steam bypass in the ESBWR is well controlled by shutdown rods, and essentially no fuel overheating occurs. In this case the "next failure" may be a delay in shutdown action, by 250 milliseconds or more. In such a case very rapid fuel heating would occur, with positive reactivity addition several times larger than the delayed neutron fraction at about 1 second. Negative Doppler reactivity would tend to reduce this reactivity addition, but fuel shattering and melting may occur. In any case, long term cooling would be essential to render the reactor safe.

In general, the consequences of "next failure" events in CANDU 6 are less than those in both the PWR and BWR.

6. Conclusions

All of the accidents here outlined involve rapid reactivity increases that might, if unchecked by engineered systems, lead to severe core damage in the long-term. Each of these reactivity increases is terminated one way or the other, and the reactor is rendered safe, by fast-acting shutdown mechanisms combined with engineered systems that provide long-term fuel cooling. The details of the event sequence, specific to each reactor type, is subject to further study as not all the information is available to the authors, particularly for plant designs other than CANDU with which the authors are familiar.

The next stage of comparison must involve the probability of occurrence of the event, as well as the conditional probability of occurrence of the "next event". This conditional probability depends on the reliability and speed of the shutdown mechanisms that accomplished the shutdown in the reference case. The final stage is to estimate the consequences of failure following the "next event". These consequences might range from safe, stable, shutdown conditions to more serious consequences such as fuel melting and release of large quantities of volatile fission products inside the containment. Under these very severe conditions the AP1000 incorporates an ex-vessel cooling system that converts the pressure vessel into a "crucible" that can stabilize and cool molten core debris in the bottom of the pressure vessel. This new design feature is conceptually similar to the severe accident cooling provided passively in CANDU reactors. In CANDU, the moderator water and the cool shield tank water surrounding the fuel channels also are fully capable of long-term (several days) stabilization of reactor core debris.

Transients submitted for licensing approval are unlikely to represent a true prediction of the event sequence being studied, because of the several "conservative" assumptions made in the models and constitutive equations. Modern analyses are trending toward more realistic models backed up with explicit provision for uncertainties. The authors of this paper expect that the calculated consequences of all RIA events in these plants will become less and less severe as these predictions become more accurate. Eventually, it is expected that CANDU reactors will be proven to be incapable of producing severe health consequences to surrounding communities.

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Further Scenes from the Conference

Making Ionising Radiation a Real Experience for High School Science Students

Jeremy Whitlock[1], Peter Lang[1], Doug De La Matter[2], Paul Hinman[1] & Bryan White[1]

[Ed. Note: This paper was presented at the 30th Annual Conference of the CNS.]

Abstract

The Canadian public has little understanding of ionising radiation due in part to its treatment in popular media. In principle, students learn about ionising radiation in their school science classes. Developments in science curricula are providing more education opportunities for this subject. The Canadian Nuclear Society's program for introducing real, personal experience with ionising radiation in the classroom is starting to make a difference. The demand is expected to exceed the resources of the CNS and the program is being developed to facilitate external support. This paper summarizes the need, the history of this program development, and the path forward.

1. Why target high school science teachers?

The objective of improving public understanding of the issues related to nuclear technology is challenging. The CNS Education and Communication Committee (ECC) perceives that the best value for effort can be obtained by enabling and equipping teachers to develop improved understanding by their students of the basic science of ionising radiation. Armed with this knowledge, these students will critically challenge positions or policies that are at odds with what they have learned. Most teachers will instruct a minimum of 25 senior science students each year.

2. Learning from Virtual Experience

Increasingly the laboratory component of physical science education for Canadian high school students includes computer-based, virtual experiments. These substitute a computer program learning environment for the expensive and in some cases potentially hazardous equipment and substances required to perform conventional laboratory experiments. It is the opinion of the authors that the quality of the learning experience suffers with this transformation to a risk-averse approach common in contemporary society.

The CNS ECC has been promoting real, personal experience with ionising radiation for teachers and students alike since 1990. The CNS ECC uses a high-sensitivity Geiger detector with both Naturally Occurring Radioactive Material (NORM) and consumer products (e.g. KCl salt substitute, smoke detectors, Vaseline glass, vintage camera lenses) as sources of ionising radiation. This approach avoids the need for identified radioactive sources in schools, and makes the experience more credible for the students.

3. History of CNS Involvement in Science Teacher Events

For many years, AECL Chalk River Laboratories operated an annual "Science for Educators" program. The Chalk River Branch of the CNS provided a "Hands-on Ionising Radiation Workshop" [1] as part of this program, initiated by former CNS member (and CNS Council member) Aslam Lone. This workshop included:

- Simple cloud chambers using dry ice and alcohol
- Opportunities to use industrial "pancake" Geiger detectors to monitor check sources with shielding materials
- A demonstration of the measurement of a half-life with ^{137}Ba using a Geiger
- A demonstration using a sensitive Geiger to monitor the soft gamma from the ^{241}Am source in an ionisation smoke detector.

Some of these demonstrations were made available to the public attending AECL Open House events. All of these activities were terminated after the unfortunate events of 2001-09-11. During this period, the CNS ECC also donated a Geiger detector to the Madawaska Valley District High School. The CNS ECC's policy at the time was much as it is today: the value of Geiger detectors in classrooms merits their donation to sufficiently interested but budget-challenged high school science departments.

For over ten years CNS member Jeremy Whitlock frequently made classroom presentations on nuclear energy as an AECL Speakers Bureau activity, often including demonstrations with a CNS-supplied Geiger detector. A few school teachers inquired about obtaining a similar detector for their schools following these presentations.

In 2006 the CNS ECC hosted a booth at the Science Teachers' Association of Ontario Annual (STAO) Conference [2]. The booth was staffed with volunteers – CNS members and others from the Canadian nuclear industry. The booth provided fact sheets prepared by the CNS ECC and material provided by the nuclear industry to interested teachers.

The Geiger detector demonstration was a key element of the booth and one was awarded as a draw prize to a teacher from Lester B. Pearson Secondary School (Burlington). Teachers visiting the booth were encouraged to contact the CNS and request a similar Geiger detector for their school. Despite ample enthusiasm evident in teachers visiting the booth, none followed up with the CNS. Senior STAO members recommended that the CNS provide workshops.

1 CNS Education and Communication Committee
2 Science Teacher (retired, Madawaska Valley District High School)

In 2007 February the CNS ECC assisted the Ottawa Branch with an exhibit booth at the Ottawa Carleton District School Board Science Professional Development day.

In November the CNS ECC again hosted a booth at the STAO 2007 conference. On this occasion a workshop on energy, targeting elementary science teachers, was also presented. Three Geiger detectors were awarded as draw prizes to teachers from St. Jean de Brébuf (York), C.W. Jefferys CI (Toronto), and Iroquois Ridge HS (Oakville). Once again, however, no teachers followed up by requesting a Geiger for their school, despite evident enthusiasm.

Concurrent with the Canadian Nuclear Association's (CNA) 2008 Conference and Trade Show in Ottawa, the CNA invited science coordinators from the provincial ministries of education to attend a meeting on the Nuclear Technology Education website being developed by the CNA to address the Pan Canadian Science Curriculum [3]. At this meeting the CNS ECC presented the CNS Geiger demonstration and advised that the CNS was interested in placing Geigers with interested teachers in high schools. Following this presentation, a request was received from a teacher from Fredericton High School, and a Geiger was presented by the New Brunswick Branch. Moreover, the representative from the NB Ministry French Language schools requested 30 Geigers. CNS Council approved a Special Project to meet this request. The CNS ECC advised both the English and French representative that funding was available for up to 30 Geigers, and requested that they coordinate their request. At this writing, 12 have been sent to the NB Branch for donation to the French NB high schools, and another 18 are on order for the English NB high schools.

In 2008 March the CNS ECC assisted the CNS Alberta Branch with hosting a booth at the Mighty Peace Teachers' Convention [4] in Grand Prairie, Alberta. A contact made at the booth lead CNS member Paul Hinman to follow up with teacher Clifford Sosnowski, and subsequently, the Alberta Branch donated a Geiger to St. Laurent High School in Edmonton.

In 2008 the CNS ECC hosted the STAO booth again. A new workshop was prepared, specifically on ionising radiation and targeting senior physics and chemistry teachers. A retired science teacher was recruited to assist with the development of the workshop and its presentation. Prior to the conference the workshop development team presented an early version of the workshop to the science department heads from high schools in the Renfrew County District School Board at a meeting in Pembroke, Ontario. Their encouragement and comments were appreciated.

Also in 2008, the CNS Alberta Branch organised a booth at the Alberta Teachers' Association Science Council (ATASC) [5] Annual Conference in Calgary, which is held each year during the same week as the STAO conference in Ontario. The CNS ECC assisted the Branch providing material, equipment and suggestions. CNS member Peter Lang presented the workshop in Calgary on the same day the same workshop was presented in Toronto. At both venues the workshop was well-received. No Geigers were awarded as draw prizes in these cases, but follow-up interest was finally demonstrated: eleven teachers from STAO (one responding immediately after the Pembroke meeting) and two from ATASC have requested Geigers to date. Geigers are being sent to the schools as they become available. The list of schools that have received Geigers from the CNS is posted on the CNS website [6].

In 2009 February the workshop was presented at the Ottawa Carleton District School Board 2009 Science PA Day to two groups of 11 teachers. The Ottawa Branch presented a Geiger to a teacher from Merivale High School during the workshop and hosted a booth at this event in Bells Corners. The workshop was well-received, but to date, no requests have arisen from this instance. The workshop was presented at the Atlantic Canada Association of Science Educators (ACASE/AEESA) [7] Annual Conference in Moncton, NB May 22nd & 23rd, 2009.

4. Ionising Radiation Workshop

The CNS Ionising Radiation Workshop is designed to include material useful for the introduction of the theory of radioactive decay. It enriches the curriculum with an introduction to the Interactive Chart of the Nuclides [8] and real classroom measurements using a Geiger detector. The workshop includes proposed experiments with examples of the data that may be obtained and an analysis of the results.

The workshop notes include detailed information on setting up the Geiger system and software. This is necessary because a teacher may use the system only once or twice a year, and may have to reinstall the software routinely. Supplementary material illustrates how the Geiger system may be set up using a variety of computer interfaces. The limitations of the USB interface option are illustrated, and means to reduce the intensity of some sources with shielding / collimation are shown.

The Power Point slide set and notes are made available to teachers for downloading from the CNS web site [1].

The experiments with NORM and consumer sources illustrate that real experimental results are more complex than the simplified illustrations in textbooks suggest.

The outline of the workshop notes is appended to this paper.

5. Aware Electronics RM-80 Geiger

The experience gained over almost two decades of presentations with these instruments has established that a high sensitivity Geiger detector interfaced with a MS-Windows®-based program is necessary. People in general and students in particular respond best to results that are obtained expeditiously.

The sensitivity of the RM-80 Geiger supplied by Aware Electronics [9] is sufficiently high to provide background count rates of 40 to 50 counts per minute in any Canadian venue. It is important for the students to observe that ambient background is readily detected. Moreover it is possible to introduce simple shielding and reduce the background – but not eliminate it. The information provided illustrates that detecting weak sources requires long counting intervals.

The software generates a time-series bar graph with alarm detection and annunciation features. Since the data is displayed on the computer monitor it can be readily projected on a screen for classroom viewing, and the data may be logged for subsequent analysis using a spreadsheet.

The Aware product interfaces to a computer serial port (or a parallel printer port) so as to generate a processor interrupt for every count event. Contemporary laptop computers include

neither a serial port nor an internal bus interface where one may be added (e.g. PCIA slot). However, Universal Serial Bus (USB) connected serial ports may be used.

Unfortunately the USB interface data transfer is non-deterministic and consequently the statistical properties of the Geiger count timing are not preserved. Moreover, the USB interface scheme limits the maximum count rate and some experiments require measures to reduce the maximum count rates to minimize missed events. Aware Electronics also market a more costly, higher-performance microprocessor-based USB interface.

6. Scale of the Demand for Geigers

With each presentation of the workshop an additional demand for Geiger detectors is anticipated. 2009 will provide additional experience to gauge the success of this approach. Figure 1 illustrates the experience to late May and the target CNS donation numbers for 2009 and 2010.

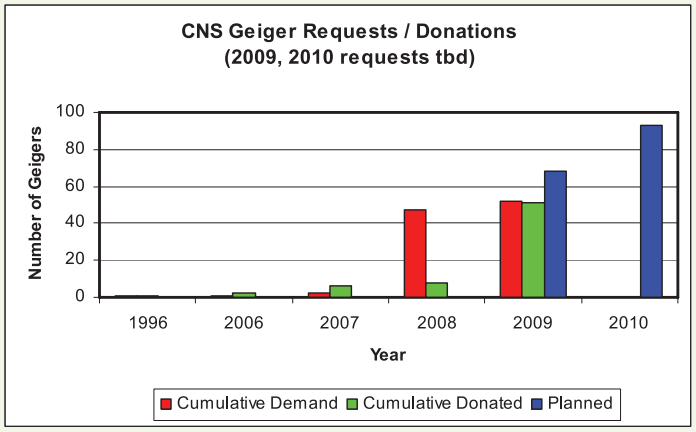

Figure 1: History and Projection of Cumulative Donations to Schools

Within a given school district there is the opportunity for teachers to share a Geiger among several schools. This is limited since all the teachers in a province follow the same curriculum and their requirement for these instruments will tend to be concurrent.

The distribution of the Geiger kit donations are shown in a Google Earth® image of Canada. The white markers are associated with requests arising from visits to schools. The blue markers arose from the Alberta Teachers' Association Science Council Conference in Calgary. The pink markers resulted from the Science Teachers Association of Ontario Conference in Toronto. The green markers indicate the donations to New Brunswick schools. Those with a black star are French language schools.

Table 1 lists an indicative number of secondary schools (in some cases K-12, and single-room schools) for the respective provincial / territorial ministries of education.

Some rural schools have very few senior students, while those in large centres may exceed 100. The opportunities to help improve science education in Canada are formidable.

A program that targets specific communities or districts important to the industry, and large urban secondary schools is thought to offer the best return on an investment of this kind.

Figure 2: Google Earth® Illustration of the Distribution of Geiger Kit Donations.

7. A Matter of Trust

The premise behind the donation of Geiger systems to the schools is that the teachers are to be equipped and enabled to provide improved science education. Consideration has been given to attempting to track the usage of Geigers in the schools. The reality in most schools is that teachers are frequently assigned to teach different classes. Moreover they have many administrative duties, and reporting the status of a donated item is not likely to be sustained. Rather than actively tracking the Geigers, the list of schools with Geigers is posted on the CNS website. Through regular presentations of the workshops, the CNS trusts that interested teachers will recover a disused Geiger and ensure it is returned to service in the classroom.

Table 1
Indicative Estimate of Secondary Schools in Canada

Province / Territory	(Senior, K-12) Secondary
Alberta	654
British Columbia	364
Manitoba	320
New Brunswick	72
Newfoundland and Labrador	74
Northwest Territories	19
Nova Scotia	100
Nunavut	10
Ontario	892
Prince Edward Island	9
Quebec	478
Saskatchewan	151
Yukon	3
Total	3146

8. Moving Forward

This CNS ECC program is moving forward with the following specific objectives:

- Establishing a robust system to supply and distribute Geigers;
- Establish a dedicated kit for workshop presentations with a robust method of checkout, deployment and recovery;
- Maintaining a stable of experienced workshop presenters including:
  - o CNS volunteers (free)
  - o Retired or active senior science teachers (honoraria), and
  - o Professional presenters (contract services);
- Developing a business case to encourage industry participation
- Developing a French language workshop, material, and French speaking presenters.

9. Acknowledgements

The continued support of CNS Council has made the development of this program possible. Chuck Cohen (Community Hebrew Academy of Toronto) provided encouragement and guidance starting at STAO 2006. Clifford Sosnowski (St. Laurent High School, Edmonton AB) provided useful comments and advice. The volunteers who staffed the booths at the events in Toronto, Ottawa, Grand Prairie, and Calgary are most appreciated. In particular, those who are not CNS members include: Cheryl Cottrill (WiN Canada), and Bob Walker (PWU, OPG). In 2006 and 2007 Candesco staff assisted with the booth (including members of the CNS and non-members).

10. References

[1] CNS website Education page, www.cns-snc.ca/ecc/cnsecc.html.
[2] Science Teachers' Association of Ontario, www.stao.ca.
[3] CNA website, www.cna.ca/curriculum/default.asp.
[4] Mighty Peace Teachers' Convention, mptc.teachers.ab.ca.
[5] Alberta Teachers' Association Science Council, sc.teachers.ab.ca.
[6] CNS website Education Page donation list, www.cns-snc.ca/ecc/Geiger_donations.pdf.
[7] Atlantic Canada Association of Science Educators, www.unb.ca/fredericton/science/physics/acase/.
[8] Interactive Chart of the Nuclides, www.nndc.bnl.gov/chart/.
[9] Aware Electronics website, www.aw-el.com.

Appendix

Table of Contents of the
CNS Ionising Radiation Workshop Notes

Bryan White teaching teachers.

W.B. LEWIS MEMORIAL LECTURE

The Future Nuclear Vision

by D.F. Torgerson, Emeritus Senior Technology Advisor, Atomic Energy of Canada Limited

[Ed. Note: This W.B. Lewis Memorial Lecture was presented at the 30th Annual Conference of the CNS.]

Abstract

We are on the threshold of unprecedented changes in the global nuclear community. The various factors affecting these changes can be classified into the following main drivers: 1) environmental concerns 2) economics, 3) population growth, and 4) energy security. A major consequence will be the expansion of operating nuclear power plants from the few hundred we have today to a few thousand by the end of this century. This expansion will present challenges and opportunities in every area of the nuclear industry, including design and development, construction, supply, operations, maintenance, regulation and safety, decommissioning, and the entire nuclear fuel cycle. The creative innovation that characterized the birth of the nuclear power industry is needed in all these areas to address fully the challenges and opportunities. Some aspects of thorium fuel cycles are used to illustrate this point.

1. Introduction

W.B. Lewis and his colleagues established the technical foundation of the Canadian nuclear industry and the CANDU© reactor during a period of intense creativity and innovation[1]. Indeed, it can be argued that almost every major concept we have today was originally considered or developed during Lewis' era. This initial outburst of underlying innovation has been followed by an important period of development that has seen enormous advancements in safety, design, delivery, supply, and operation of CANDU reactors.

But in addition to this, it is my belief that the time has come to re-examine on a more fundamental basis all aspects of our technology and in so-doing, perhaps challenge some of the conventional approaches. It is opportune to do so since our industry's growth will attract new generations of talented people who will undoubtedly bring new perspectives to technology directions.

This lecture is divided into 3 parts. First, we will examine the drivers that are likely to shape our industry over the next few years and the consequences of these drivers. Second, thorium fuel deployment will be used as an example of an important technology that requires advancement to ensure sustainability for the very long term. Third, we will consider the fission process itself to see if a more fundamental look at the various components of fission could lead to some speculative ideas on what could be done in the much longer-term future to enhance fuel and fuel cycles. The intent of the latter topic is to stimulate some out-of-the-box thinking on how we might advance well beyond where we are today since I believe we still have a long way to go to realize the full potential of nuclear power technology.

2. Drivers shaping the nuclear industry

The drivers for growth of the nuclear industry can be classified into four main topics: environment, economics, population growth, and security of energy supply. In characterizing the key drivers, I have drawn extensively on information from the OECD/NEA Nuclear Energy Outlook (NEO) published late last year [1].

2.1 Environmental concerns – global warming

Global warming has become an increasingly urgent international issue since the 2007 update report by the Intergovernmental Panel on Climate Change (IPCC) [2]. The IPCC states in this report that as the result of additional research, the probability that anthropogenic emissions are affecting climate change is now greater than 90%. At the recent 2009 March Copenhagen meeting to update the 2007 report, the climate researchers issued the following press release: "The worst-case IPCC scenario trajectories (or even worse) are being realized ... There is a significant risk that many of the trends will accelerate, leading to an increasing risk of abrupt or irreversible climatic shifts" [3].

Power generation is not only the largest source of CO_2 emissions, but it is also the most rapidly growing source, as indicated in Figure 1. In addition, the recent rate of the increase appears to be accelerating.

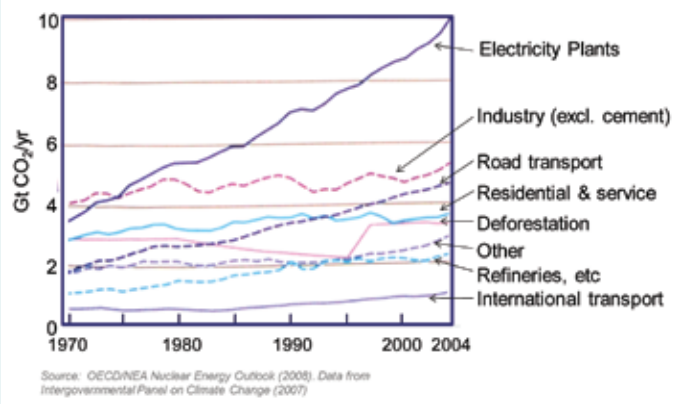

Figure 1: Sources of anthropogenic carbon dioxide emissions.

1 CANDU is a registered trademark of Atomic Energy of Canada Limited.

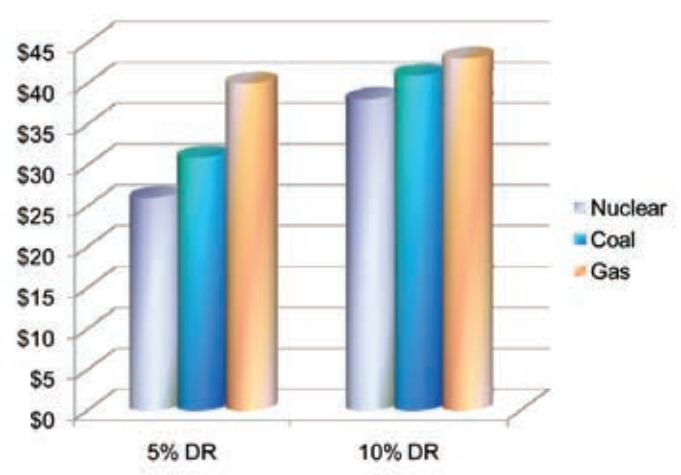

Figure 2: Levelized unit energy cost in US$ for electricity generation in Canada. Source: OECD/NEA/IEA (2005), reported in [1].

Although other emissions sources sometimes receive considerable publicity (such as the oil sands industry in Alberta), the data show clearly that electricity generation is the critical area to focus the main effort to reduce emissions. Also, while all approaches to CO_2 emission reductions such as conservation have a role, the reality is that the only way to seriously address emissions is to include in the various measures an aggressive new-build nuclear reactor program. Nuclear power is the only large-scale energy generation technology that can be widely deployed before the end of the century to address the emissions issue.

2.2 Economics

The second major driver is economics. The OECD/NEA NEO considered the cost of generation in OECD countries, and the results for nuclear, coal, and natural gas in Canada are shown in Figure 2. Since Canada is one of the most competitive countries in the world with respect to electricity production, one would expect that if nuclear energy is competitive here then it can be competitive everywhere.

Contrary to some perceptions, the actual data show that nuclear power in Canada is the least expensive choice. If additional charges are levied for the environmental cost of carbon dioxide emissions, this cost advantage will increase significantly. Moreover, the cost of nuclear power is relatively insensitive to the cost of fuel. The OECD/NEA NEO states that a doubling in the cost of fuel would raise electricity costs by 75% for natural gas, 40% for coal, and only 4% for nuclear [1]. Therefore, costs are both lower for nuclear and are relatively stable even with the inevitable fluctuations in fuel costs. Such long-term steady costs will benefit competitiveness and strategic planning by industry.

It is also of interest to consider how Canadian nuclear plants compare with other OECD countries. These data are presented in Figure 3. It is perhaps remarkable that Canadian plants produce electricity at costs below those of many other countries including those that operate many more plants with the benefit of economies of scale.

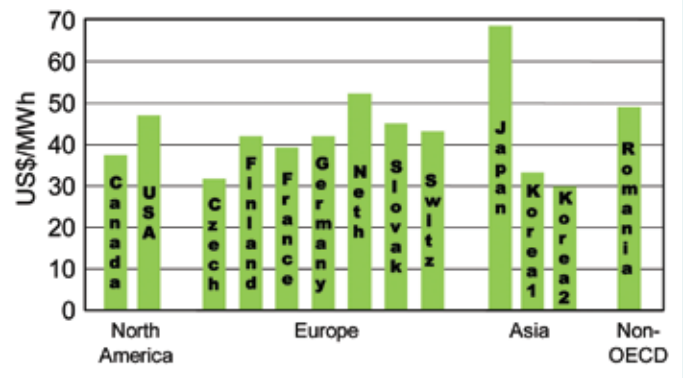

Figure 3: Nuclear power levelized unit energy costs for OECD countries. Data from OECD/NEA NEO (2008)

2.3 Population growth

The world's population growth will undoubtedly have a major impact on the deployment of new nuclear power plants. The United Nations most recent medium scenario is that the world's population will increase from under 7 billion people today to more than 9 billion by 2050. Also, there is the continuing aspiration for human development throughout the world. This will create a demand for electricity that will exceed that due to the population increase alone since electricity is the engine of growth, particularly for the new knowledge-based economies.

In addition, we will see new pressures on the basic requirements for human survival, such as fresh water. The annual increase in the consumption of fresh water is 64 billion cubic meters, which, to put this increase into context, is about the annual volume used by Egypt [4]. Even in developed countries, fresh water is becoming an important issue. As a result, desalination has increased from almost nothing in the early 1970s to more than 3.5 million cubic meters per day in 2004 [1].

2.4 Energy security

Energy security has three main considerations: 1) the world supply of uranium, how long that supply can be accessed economically, and the prospects for extending uranium resources; 2) securing a domestic source of fissile material for those countries that do not want to depend on the continuing reliability of imports; and 3) the ability to store fuel locally to overcome any short term disruptions in the supply chain.

As discussed later in this lecture, uranium supply appears to be secure for the next few decades depending on the rate of nuclear power growth. Even when conventional supplies become scarce or expensive, advanced fuel cycles could extend fuel resources indefinitely. Domestic supply of fuel can be secured by developing fuel cycles that extend uranium supplies or that breed sufficient new fuel for a closed cycle. Owing to the very small amount of fuel required to operate a nuclear power plant and the fuel's high stability, fuel can be stored locally for relatively long periods of time. Therefore, there is considerable flexibility when developing nuclear fuel security policies that does not exist for other fuels.

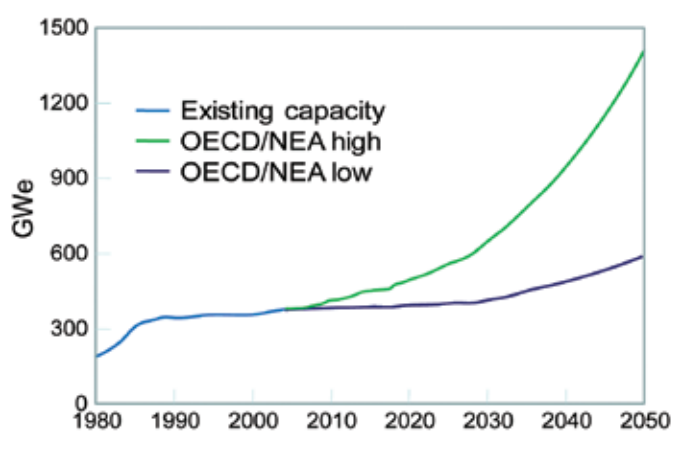

Figure 4: OECD/NEA predictions for nuclear growth to 2050.

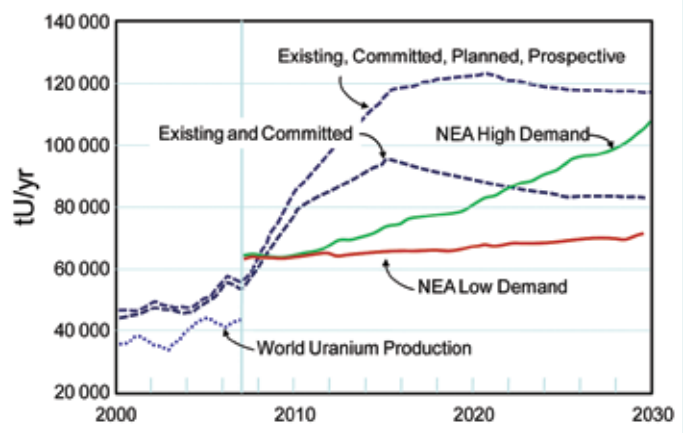

Figure 5: NEA NEO assessment of world uranium supplies [1].

3. Effect on nuclear power growth

The World Nuclear Association, the International Atomic Energy Agency, and the OECD/Nuclear Energy Agency have all assessed the prospects for the future expansion of nuclear power and have come to similar conclusions. In what follows, for consistency I will draw once again on the OECD/NEA NEO [1].

Figure 4 shows the low and high NEA scenarios. The low scenario assumes there will be little growth in the number of nuclear plants but that older smaller plants will be replaced by larger 1000 MWe plants. The high scenario appears to have a slope similar to the rapid increase in capacity in the 1970s and early 1980s. The NEA has determined that the nuclear industry is capable of meeting this demand. Owing to the drivers discussed above, I believe we need to plan for the high scenario and even for scenarios that go beyond these estimates. The implications are that by the end of this century the world will be operating a few thousand nuclear plants in contrast to the few hundred plants today.

4. Fuel supply

The rapid increase in nuclear power raises the question of long-term fuel supply. Figure 5 shows the overlay of the NEA growth projections on the supply of uranium. The overlay suggests that uranium supplies are quite adequate to meet demand until at least 2030 and beyond. It is unusual for a mineral resource to have a secured supply for such a long period of time. Also, from past experience we can expect the uranium mining industry to respond to the increase in demand and that the high scenario fuel supply requirements will be achieved.

However, the rapid expansion of nuclear power will put additional emphasis on the supply issue over longer periods of time. To commit to a 10-fold increase or more in nuclear power, decision-makers will have to be confident that the large upfront investments that are required will not be undermined by fuel supply over the likely 60+ year lifetime of the plants. In addition, a sharp increase in the use of nuclear fuel will likely raise concerns about the eventual disposition of nuclear waste in some countries, particularly where progress on deep geologic disposal has been slow. Finally, even though world nuclear fuel resources may be plentiful, some nations will want to develop local supplies by exploiting their indigenous resources of thorium. For all these reasons, fuel cycles will receive considerably more interest in the coming years.

5. Reactors and fuel cycles

Two key questions are the type of reactors and the types of fuel cycles the world will adopt. The answer to these questions will depend on the complex interplay between economics and policy. While policy will drive the initial efforts, as in all things, economics is likely to be the main consideration for longer-term sustainability.

5.1 The dominance of water-cooled reactors

Currently, the only commercially successful reactor type that is still being built today for power production is the water-cooled reactor. We have considerable experience with the design, safety, and operation of these reactors, which are major factors for managing the risk associated with large capital investments. Moreover, the major reactor vendors have just invested considerable resources to develop state-of-the-art Generation III technology and it is likely that they will need to recover these investments over the next few decades when the major expansion of nuclear power will occur.

For all these reasons, the rapid large-scale deployment of nuclear power using water-cooled reactors will likely predominate until other reactor types prove to be more compelling. But the full commercialization of other reactor types may take several decades. Therefore, to meet the urgent needs created by the drivers discussed above, it seems to me that we will need to focus on thermal reactors and not wait for new technology that will be available at some uncertain time in the future. This is not to say that such development is unnecessary; it simply accepts the economic reality that most if not all new commercial nuclear plants over the next few decades will be water-cooled thermal reactors.

Therefore, in what follows I will concentrate on the deployment of water-cooled reactors in future fuel cycles[2].

5.2 Fuel cycles

There are many considerations for the deployment of future fuel cycles: economics, waste management, proliferation resistance, policies, lead times, and technology.

Fuel cycles can be classified into three underlying strategies. The first strategy is the once-through cycle where the fuel is used in a reactor and is then treated as a waste. This is the category currently followed by most nuclear power nations. The second strategy is the recycling of spent fuel to extract the remaining fissile material before disposing of the waste. This strategy extends the supply of uranium but requires the implementation of relatively complex reprocessing technology, the full benefit of which may not be realized if this is considered the end point for fuel cycle development. The third stage is to develop self-sufficient cycles which are largely independent of an external supply of uranium. This stage requires a fuel and reactor that can breed new fissile material.

From a purely economics point of view, the once-through fuel cycle is very compelling. The entire cost of the fuel cycle, including the safe permanent disposal or retrievable storage in deep geological structures, is included in the cost of power generation. This has proved to be a sustainable economic model and as we saw earlier, the price of nuclear electricity is very competitive with all other forms of electricity production even though nuclear electricity prices include the costs of waste disposal.

The second strategy is aimed primarily at spent LWR fuel with a fissile Pu content of about 0.6% and a fissile U-235 content of 0.9%, depending on burnup and initial enrichment. For this approach, the Pu is extracted from the fuel and burned in LWRs. The wastes include fission products and the minor actinides, but the major by-product is the recovered uranium (RU) containing 0.9% U-235. The Pu from LWRs would eventually be used to fuel fast reactors, which would in turn breed additional Pu from U-238 for self-sufficiency.

The alternative to breeding Pu-239 from U-238 using fast reactors is to breed U-233 from Th-232 using thermal reactors. The U-233 could be used to extend uranium resources (strategy 2) or even to achieve a self-sufficient closed cycle (strategy 3).

Proponents of advanced fuel cycles will argue that we need to make better use of existing resources, since in the once-through cycle we are currently leaving more than 95% of the energy generation potential in the used fuel. Advanced fuel cycles are required to ensure the sustaining of nuclear power well beyond the current supply of uranium that is relatively inexpensive to exploit. Some proponents will also argue that we should endeavour to reduce nuclear wastes, particularly long-lived minor actinides, in the spent fuel by devising strategies to burn the waste in current and future reactors. This will become more urgent as fuel wastes increase in proportion to the increase in nuclear capacity. Finally, there is the policy driver mentioned above for fuel supply security in some countries that do not have sufficient indigenous uranium supplies to support their nuclear program.

However, if new technologies such as fast reactors and conventional reprocessing are established and integrated into the cost structure, there is a question of whether the cost of generation will still be competitive. Therefore, I believe there is considerable incentive to look at the existing thermal nuclear plants and their role in future fuel cycles. In particular, the wide-spread belief that the fast reactor/reprocessing route is the only way to sustain nuclear power in the longer term needs to be examined carefully. It is prudent to consider an alternative since a single approach to future sustainability is not without risks.

6. Thorium fuel

The various thorium fuel cycles have been well-documented [5]. I consider only three topics in this lecture – the use of U-233 for thermal breeding, a comparison of uranium and thorium fuel, and recycling using dry decontamination of spent thorium fuel.

6.1 Why U-233 is used for thermal breeding

The starting point for all advanced fuel cycles is the availability of neutrons. In particular, we want the smallest possible (n,) absorption by fissile isotopes, which has the dual negative effect of removing both fissile fuel and neutrons. For breeding, a minimum average of two neutrons per fission is required, one to sustain fission and the other to produce more fissile material. However, since there are inevitable neutron losses in the core due to structural materials and leakage, the net average neutron generation per fission needs to be larger than two.

Figure 6 shows the average fission neutron properties for the main fissile species, U-235, Pu-239, and U-233 as a function of neutron energy, determined from ENDF/B VII cross section data [6]. The red solid line is the average number of neutrons produced per fission event, usually designated . As might be expected, Pu-239 has a higher as it is a larger nucleus. However, the most important neutron parameter, designated , is the green dotted line which is the average number of neutrons remaining after correcting for the self-absorption of neutrons in the fissile nucleus.

Fission cross sections for fast neutrons are more than two orders of magnitude smaller than for thermal neutrons. However, the number of neutrons produced per fission increases sharply with incident neutron energy in the fast region. As well, the (n,) reaction cross sections are decreasing more rapidly with energy than the fission cross sections. The fission cross sections then level off and more reaction channels open up, such as (n,n f) and (n,2n f). The net result is that there are more neutrons available per fission event for sustaining fission and for breeding, notwithstanding the smaller cross sections.

Figure 6 also shows why a breeding cycle based on U-235 in a thermal reactor is not possible. The η values are 2.05 in the thermal region, which is not sufficient to sustain breeding. Pu-239 is also not suitable for thermal breeding since its η value in the thermal region is only 2.18 and in a harder spectrum actually dips well below 2. On the other hand, Pu-239 is an excellent fuel for breeding in

2 The Generation IV Super Critical Water Reactor is the only Generation IV reactor that is based on water cooling. The NRCan program builds on the CANDU reactor and, therefore, is an advanced evolution of the water cooled reactor.

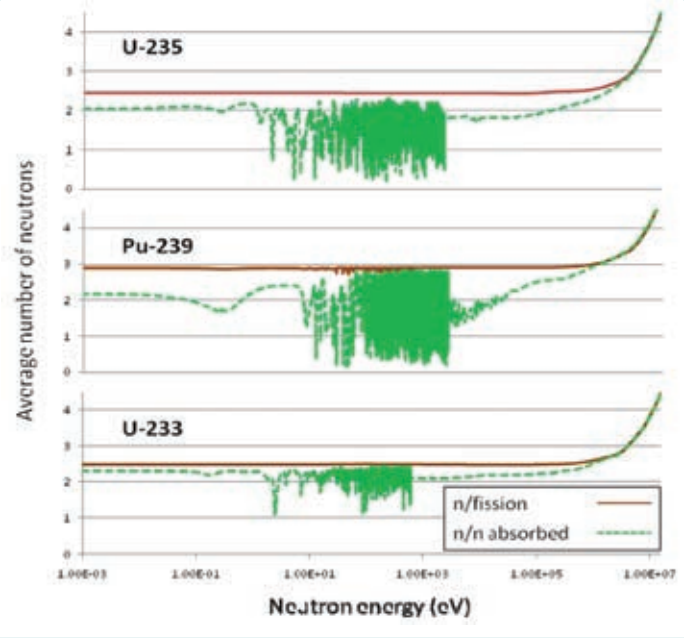

Figure 6: Neutron ν (average neutrons/fission, red line) and η (average neutrons available per neutron absorbed, dashed green line) values for the three main fissile isotopes.

the fast neutron region above 100 keV, with η values approaching 3 at 1 MeV. But only U-233 is suitable for thermal breeding with η = 2.31 and is, therefore, the only fissile isotope that can form the basis for a thermal breeding cycle. The CANDU reactor, with its high neutron efficiency, is particularly well-suited for this fuel cycle.

It is interesting to note that even in the resonance absorption region the U-233 η values are ≥ 1. This means that U-233 might also be suitable for a homogeneous core reactor where the moderator and fuel are mixed. With other fissile material, a homogeneous core would quickly lose its neutrons in the resonance region.

6.2 Actinides in thorium and uranium fuel

Figure 7 shows the build up of actinides when a cubic centimetre of uranium and a cubic centimetre of thorium are subject to the same thermal flux over the same length of time. (Note that we are ignoring fast neutron reactions in this simple assessment.)

At steady state, where we are burning U-233 as fast as we are producing it, the U-233 concentration in thorium is quite high – 1.5%. If thorium fuel pins are introduced into fuel bundles with uranium driver fuel, then at first some additional U-235 is required to breed U-233. However, the U-233 builds up over time with the net effect that the amount of U-235 needed in the core is reduced, thus improving uranium utilization [5]. If a direct recycling scheme is employed, whereby thorium fuel pins are recycled without any reprocessing so they can achieve high burnup, then uranium requirements could be reduced by 33% from the already highly efficient natural uranium cycle. In addition, the irradiated thorium pins could be stored for future extraction of the U-233, which would further improve uranium utilization.

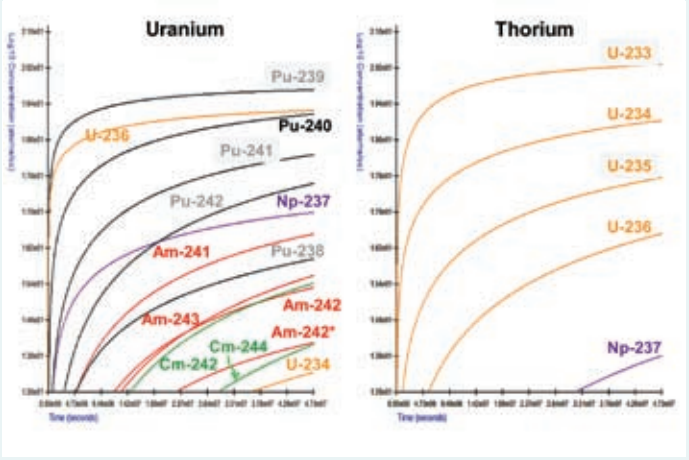

Figure 7: Long-lived actinide isotope build-up in uranium and thorium at a thermal neutron flux of 4.3e13 for one year. The original target material concentrations (U-238, U-235, and Th-232) and shorter-lived transient species (e.g., Pa-233) are not included. The major fissile isotopes have a shaded background.

If a recycling scheme is developed where the fission products are removed from the spent thorium fuel, then the U-235 requirements can be reduced considerably further, by a factor of 4. Thorium fuel recycling technology is also essential for the ultimate development of a self-sufficient equilibrium cycle where the reactor breeds the same amount of U-233 as is present in fresh fuel.

From Figure 7, one of the key advantages of thorium is immediately apparent. Uranium in a thermal neutron flux produces a relatively large number of long-lived actinide isotopes. Thorium, on the other hand, produces much less long-lived minor actinide material and, therefore, is considered to be a much cleaner fuel.

It is also noted that considerable U-236 builds up in irradiated uranium. This isotope is a neutron poison in LWRs but has little detrimental effect in the softer CANDU neutron spectrum. For this reason, the recycling of the recovered uranium from spent LWR fuel in CANDU reactors is very attractive, particularly since RU, as mentioned previously, is the most abundant by-product from reprocessing LWR fuel. In addition, the high thermal flux in CANDU reactors is an effective way to destroy the minor actinides[3]. Therefore, there is considerable synergism between LWRs and CANDU PHWRs that I believe will be increasingly exploited as the requirements for waste destruction and higher uranium utilization grow [7].

6.3 Dry processing

6.3.1 DUPIC

An alternative approach to conventional uranium fuel reprocessing is the DUPIC cycle (DUPIC = Direct Use of PWR Fuel in CANDU reactors) [8]. This approach makes use of the fact

3 The thermal flux in a CANDU reactor fuelled with actinides in an inert matrix approaches the fast flux vaues in an FBR.

The Ten Most Abundant Stable and Long-Lived Fission Products in Fuel*	UO_2	U_3O_8 [O_2/U=10]		ThO_2
	1000C	1000C	2000C	1000C
Zr	ZrO_2	ZrO_2	ZrO_2	ZrO_2
Mo	$Cs_2O{\cdot}MoO_3$	$Cs_2O{\cdot}MoO_3$	MoO_3(g)	Mo
Nd	Nd_2O_3	Nd_2O_3	Nd_2O_3	Nd_2O_3
Cs	$Cs_2O{\cdot}MoO_3$	$Cs_2O{\cdot}MoO_3$	Cs(g)	Cs
Ce	CeO_2	CeO_2	CeO_{2-x}	CeO_{2-x}
Ru	RuO_2	RuO_2	RuO_3(g)	Ru
Sr	$SrMoO_4$	$SrMoO_4$	$SrMoO_4$	$SrZrO_3$
Ba	$BaMoO_4$	$BaMoO_4$	$BaMoO_4$	$BaO{\cdot}ZrO_2$
La	La_2O_3	La_2O_3	LaO_2(g)	La_2O_3
Tc	TcO_3	Tc_2O_7(g)	TcO_3	Tc

Table 1: Predominant chemical species for the 10 most abundant solid fission product elements in fuel. The noble gas isotopes are not included. The listed elements comprise about 75% (atomic percent) of the fission products in spent fuel.

that there is sufficient reactivity in spent LWR fuel even loaded with fission products to operate a CANDU reactor. DUPIC has the potential to increase the energy from existing LWR spent fuel by up to 50%, which would result in a considerable savings in uranium. I will discuss DUPIC in a bit more detail since it has some relevance to a "dry processing" approach that could be used for thorium fuel cycles.

The process ultimately selected for DUPIC involves oxidation/reduction steps between UO_2 and U_3O_8 to condition the fuel for sintering into CANDU fuel pellets. The oxidation/reduction has the side benefit of removing some volatile fission products, thus increasing fuel burnup and reducing radiation fields. This can be understood by considering how the chemical species for fission products change in fuel under different temperature and oxidizing conditions, summarized in Table 1.

Table 1 includes about 75% (atomic percent) of the fission products in spent fuel as well as the broad range of chemical behaviour likely to be encountered. Under UO_2 fuel conditions, the fission products exist as oxides and oxy-compounds. On oxidizing UO_2 to U_3O_8, the fuel disintegrates to a powder, thus exposing the fission products to the added oxygen. Of the 10 most abundant fission products, half of them are expected to be volatile at temperatures below 2000 C under oxidizing conditions. At this point, I will note that an obvious but important aspect of DUPIC is that only a very small quantity of material is actually evaporated from the fuel and most of the fuel materials remain in the solid state. This means that the off-gas system is small and relatively simple.

Of course, there are many other important fission product species removed from the fuel (such as iodine), which are present in smaller quantities. In addition, there are fairly benign fission products, such as zirconium and barium that have relatively small neutron absorption cross sections and could remain in the fuel with little reactivity penalty. However, there are also some very high absorption cross section species such as neodymium that, if removed, would result in much improved fuel performance.

Table 1 also compares the chemical species in ThO_2 fuel to those in UO_2. ThO_2 is much more stable than UO2 and the oxidation potential in the fuel is, therefore, correspondingly lower. As a result, thorium fuel contains many fission product species in their elemental form. In particular, Mo is not oxidized in thorium fuel, which eliminates its propensity to react with other fission products.

We can also consider whether a DUPIC oxidation/reduction process can be developed to remove species that are volatile under reducing conditions. Figure 8 is an Ellingham diagram for three different environments surrounding the fuel (dashed lines) and for two fission products: ruthenium, which is volatile in air, and strontium, which is volatile under reducing conditions.

From Figure 8, we can see that air should start to oxidize RuO_2 to RuO_3(g) at temperatures above about 1500C. This is consistent with air sweep gas experiments at CRL where 100% of the ruthenium was released from spent fuel at about 1600 C. Of course, it is not necessary to have all the ruthenium in the gas phase since the equilibrium constantly shifts to vaporize more ruthenium as the RuO_3(g) is swept away.

It is also apparent that using hydrogen to drive off strontium as Sr(g) will only work at relatively high temperatures, at least when the partial pressure of water is maintained at 10^{-3} atm. Another approach would be to use the C/CO system at low CO partial pressures to create stronger reducing conditions, a standard procedure in metallurgy. In that case, strontium would be removed at much lower temperatures.

But oxidation/reduction will not work for some important species – for example, neodymium. For this, we would need to consider more advanced DUPIC processes where other reagents are employed, such as fluorine and chlorine. Such a discussion is beyond the scope of this paper for DUPIC; however, we shall return to this concept in the next section on thorium fuel recycling.

6.3.2 Th-232/U-233 recycling

The full potential of the thorium cycle can only be realized by separating the fission products from the irradiated fuel, so we will discuss this more detail. A DUPIC-type process would only work if the fuel is subject to an oxidation/reduction process that also breaks up the fuel lattice and allows the fission products to be exposed to the surrounding gaseous environment. Figure 8 shows that the C/CO system could be used to cycle between ThO_2 and Th, but it is not clear that this would break up the lattice. Therefore, the spent fuel may have to be broken up mechanically. In addition, we need to consider how to remove some of the high absorption cross section fission products such as Nd_2O_3, which is not volatile in either oxidizing or reducing conditions.

One approach is to treat the fuel with fluorine or chlorine to convert most of the fuel species to the halide form. This takes advantage of the fact that many fluorides and chlorides are volatile. Figure 9 shows the effect of fluorine on the thorium, uranium, and neodymium in the fuel. The U-233 in the fuel is converted to volatile UF_6, which can be separated from the rest of the species at very low temperatures. This would appear to be an effective way to "mine" the uranium from the fuel with little or no contamination from other materials. The uranium con-

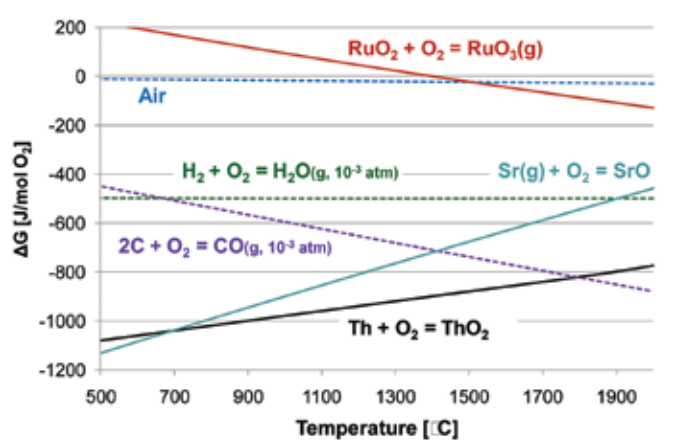

Figure 8: Ellingham diagram for ruthenium and strontium in UO_2 fuel and for ThO_2. It is noted that the fission product species activities were set equal to the mole fractions in the fuel, and the equilibrium lines for strontium and ruthenium assume that 1% of the fission products are in the gas phase.

tains U-232, which would render the fuel unsuitable for weapons applications due to the high radiation fields associated with the U-232 decay chain. However, by going to higher temperatures, it would also be possible to evaporate some of the ThF_4 with the UF_6 as well; for example, at just above 1000 C the evaporated material would be 50% uranium and 50% thorium.

The extracted uranium could be blended with fresh thorium (or with depleted or natural uranium) to provide new fuel and the fission products could be retained in the irradiated thorium. This would leave a large amount of thorium waste and would not be a particularly sustainable use of a valuable breeding resource.

To reuse the irradiated thorium removal of the fission products would also be required. Figure 9 shows that at temperatures above about 1400 C, NdF_3 becomes volatile but so does ThF_4, so there would be no separation. However, by adjusting the chemistry we have considerable flexibility to optimize the system to get the desired separations. For example, Figure 10 shows what happens in oxidizing conditions and low fluorine concentrations. This

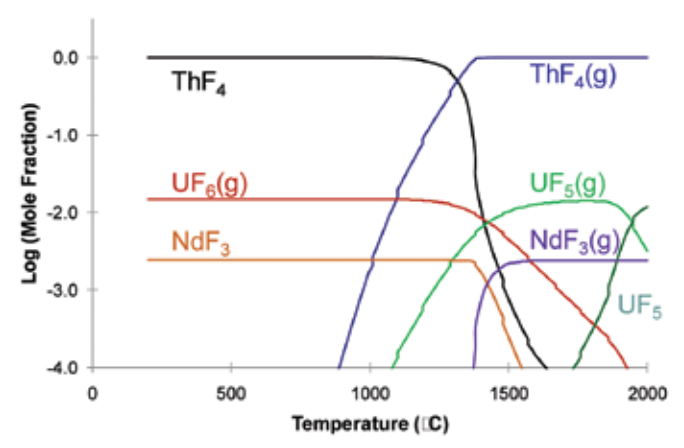

Figure 9: Species resulting from the treatment of irradiated thorium fuel with fluorine.

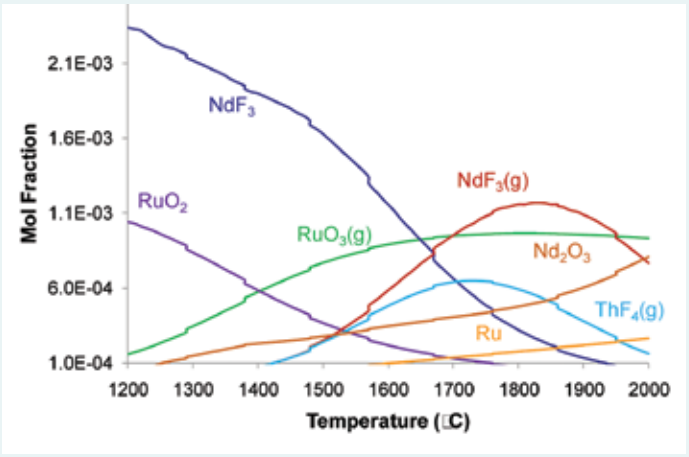

Figure 10: Thorium oxide fuel (1 mol) with 10 mol O_2 and 0.01 mol F_2.

combination was selected to stabilize the ThO_2 with excess oxygen and reduce the amount of ThF_4, while providing sufficient fluorine to convert Nd_2O_3 to the volatile NF_3. While the system needs to be optimized, Figure 10 shows that it should be possible to achieve acceptable separations. This mixture of oxygen and fluorine also retains the uranium in the solid state, so it could be used as a DUPIC-like process to remove only the fission products, thus increasing the proliferation resistance of the fuel cycle even further.

Figure 10 includes the behaviour of ruthenium under these oxidizing conditions to illustrate that other fission products would also be removed from the fuel. Obviously, these assessments are quite rudimentary and much more detailed analysis is required. Nevertheless, they illustrate the flexibility we have in developing a dry processing approach to exploit the full potential of the thorium fuel cycle.

Once again, as for DUPIC, it is emphasized that for this type of dry separation we are volatizing relatively small amounts of material from the fuel and leaving the thorium (and uranium if desired) in the solid state. This approach should be the least-cost option for dry processing and might be considered before reverting to dry processes that use bulk vaporization of all the fuel materials.

In summary, some of the key advantages of thorium are that we do not need a new reactor type to establish the fuel cycle, thorium is about three times more abundant than uranium in nature, thorium is a relatively clean fuel as far as the minor actinides are concerned, and if we focus on the underlying chemistry we should be able to develop a relatively simple dry process for recycling. This would extend uranium resources in the short term and would lead progressively and logically to the development of a self-sufficient cycle.

7. Fission – can we do more than heat water?

As a final topic, I would like to pose the question "are we getting everything we can from fission?" I am reminded that nuclear power is still a very young technology and that to date we have only used the remarkable process of fission to heat up water. The conversion of fission energy to heat is very efficient, but more than

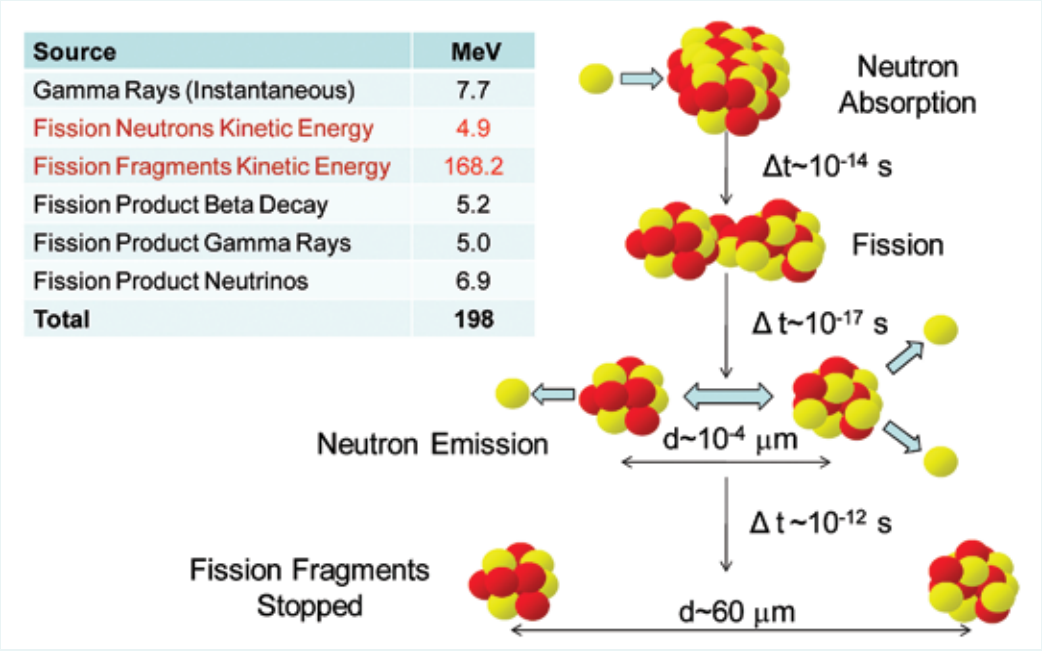

Figure 11: The fission process.

60% of the energy is lost when we convert the heat to electricity. I would be disappointed if, by the end of this century, we are still thinking of nuclear fuel as only a heat source. So, the final part of this lecture is admittedly highly speculative but it is meant to stimulate the imaginations of future generations of nuclear experts who will undoubtedly come up with their own ideas.

Figure 11 summarizes the fission process. When a fissile nucleus absorbs a thermal neutron that causes fission, energy is carried away by a number of processes. Here, I will consider the two processes that create energetic particles – fission neutrons and fission fragments. In these processes, the energy is concentrated in just a few particles. Ultimately, we make use of the concentrated energy by allowing it to dissipate throughout the fuel as low grade heat.

Could we make better use of this concentrated energy before it is dissipated? I believe this to be the case, but we are going to have to expand considerably our conceptual thinking about fuel to include highly advanced fuel designs that go far beyond our current approach. Fortunately, on-power refuelling and the simple CANDU fuel bundle design provide considerable flexibility, which is a good starting point.

7.1 Fission neutrons and "fusion-enhanced fission"

Fission neutrons carry off about 5 MeV of kinetic energy, with an average energy per neutron of about 2 MeV[4]. The fission neutrons initially interact with fuel atoms and lose energy until they escape to the moderator with remaining energies around 100 keV. The energy loss, on average, is much smaller for collisions with heavy nuclei such as U and Th (~0.8 %) compared to collisions with O (~11%), so most of the energy is lost in collisions with the lighter nuclei.

Let's suppose that an advanced fuel design allows the fast neutrons to interact with deuterium (D) and tritium (T) nuclei. For example, the fuel could be a hydride of D and T, or the fuel design could be more sophisticated with zones of high density D and T to absorb the energy. In any event, most of the neutron energy would be transferred to these nuclei. The average energy loss per collision is 44.4% for D and 37.5% for T. Perhaps 5 D/T recoils would result from each neutron before it escapes from the fuel, or about 12 recoils per fission. The D/T recoils would have kinetic energies ranging from 900 to 50 keV and would collide with stationary D/T nuclei in the fuel. The peak in the cross section for the fusion reaction D + T = He(3.6 MeV) + n(14 MeV) occurs at ~110 keV for a D particle on a stationary T target and at ~190 keV for T on a stationary D target. Therefore, we are in the right energy range, particularly since the higher energy recoils will pass through the high cross section energy zone as they continue to lose their energy to the target atoms. However, these are sub-coulomb barrier reactions, so the peak cross section is only 5 barns. Nevertheless, with a dense target of D and T, the reaction rate could possibly be optimized.

There are many potential advantages to this approach. We are using a small amount of the neutron's energy to drive an exothermic reaction to gain an additional 17.6 MeV. Those D and T recoils that do not undergo fusion will simply transfer their kinetic energy to the fuel so no energy is lost. But more importantly, we are gaining extra neutrons that produce fast fissions with very high neutron multiplicities and values. Thus, we increase the number of neutrons available for breeding and also gain additional energy from the fission process. In addition,

4 Note that the most probable fission neutron energy is about 1 MeV, with a distribution tail extending out to higher energies, such that the average neutron energy is closer to 2 MeV.

since the neutron energy is well above the threshold for U-238 and Th-232 fission, we effectively increase the amount of fissile material in the fuel. The fast fission factor, which is already high for CANDU reactors, is increased. At the same time, a by-product of CANDU reactor operation that may be considered a waste – tritium -- is turned into energy.

Of course, there are also very many challenges – for example, how we would handle the generated He and the increase in U-232 from fast neutron reactions. Therefore, we can only speculate whether such an approach could be engineered to work. But it is an example of how we might reconsider the fundamentals to enhance fuel performance and to move closer to a self-sufficient thermal breeding cycle using thorium.

7.2 Fission fragments

Fission fragments carry off 85% of the energy arising from fission. Again, we take an intense source of energy and allow it to dissipate as low grade heat to eventually heat up water. If we could devise a way to more directly tap into the fission fragment energy to create electricity, then we could increase the efficiency of nuclear power by avoiding the losses associated with generating electricity from steam.

We can use the SRIM Monte Carlo code to determine how the fission fragments lose energy to the material in which they are travelling [9]. The fission fragments transfer about 96% of their kinetic energy to ionization in the fission fragment track[5]. The electrons from the ionization in turn produce electron cascades surrounding the track. This intense displacement of charge eventually dissipates as the electrons become thermalised and recombine with the positive ions, transferring their energy to the fuel. The question we might ask is whether there are better ways to make use of this dense electron/ion region before it degrades to low grade heat. For example, a fuel design where the fission fragments recoil into a gas could facilitate the collection of charge or a more sophisticated approach would couple directly electromagnetically. However, I will not attempt to address further this complex but intriguing question in this lecture, but will leave it as a challenge for others to ponder for the long-term future.

8. Concluding remark

A key point I have tried to make in this lecture is that given the inevitable rapid future expansion of nuclear energy, now is the time to think about how we are going to advance our technology over the coming few decades and even over the rest of the century. If we do this properly with an appropriate balance between shorter term development and longer term advanced innovation, then the future is going to be as exciting as we choose to make it. And I think that is exactly what W.B. Lewis would have expected.

5 The 4% enrgy loss not accounted for by transfer to electrons goes into nuclear stopping. This would also create D and T recoils in a mixed hydride fuel, some of which have energies sufficient to cause fusion. A preliminary assessment indicates that about 2.5 recoils capable of undergoing fusion would occur per fission.

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GENERAL news

(Compiled by Fred Boyd from open sources)

Selected from open sources. Note, because of the deluge of media coverage of the NRU – MAPLE – isotope affair no news items related to that topic have been included. However, readers may find interesting and informative the webcasts of the series of hearings held by the Standing Committee on Natural Resources held in mid June.

F.B.

Cameco resumes UF6 production

Cameco Corporation announced in mid June that it had resumed production of uranium hexafluoride (UF_6) at its Port Hope, Ontario conversion facility.

Production of UF_6 at the facility has been suspended since December 2008 as the company could not obtain a supply of hydrofluoric acid (HF) on acceptable terms. In May 2009, Cameco announced that it had signed a contract with its historic supplier of HF under terms that are mutually beneficial to both parties. HF is a primary feed material for the production of UF_6.

Cameco continues to make progress in negotiations with other suppliers to broaden and diversify its supply base.

The Port Hope plant uses a chemical process to convert U_3O_8, uranium concentrate powder, to gaseous UF_6, the feedstock for uranium enrichment facilities. A separate process is used to convert U_3O_8 to UO_2 for CANDU fuel.

Restart of UF_6 production in Port Hope does not alter Cameco's 2009 fuel services production forecast of 8 to 12 million kilograms uranium.

IAEA Completes Review of CNSC

On June 12, 2009, the Integrated Regulatory Review Service (IRRS) from the International Atomic Energy Agency (IAEA) concluded its two-week mission to Canada. Peer review team leader, Shojiro Matsuura, and deputy team leader, Martin Virgilio, presented the team's high-level findings to Canadian Nuclear Safety Commission (CNSC) President Michael Binder.

Overall, the review team has determined that Canada has a mature and well-established nuclear regulatory framework and that the nuclear regulator does an effective job in protecting the health, safety and security of Canadians and the environment.

The 21-member peer review team, comprised of senior regulators recruited by the IAEA from 13 member countries, spent two weeks comparing Canada's nuclear regulatory practices with international standards and equivalent good practices elsewhere in the world. Team members interviewed government officials, CNSC staff and licensees, visited CNSC site and regional offices, observed inspections and a Commission Tribunal proceeding, and reviewed a variety of regulatory documents over the course of the mission.

CNSC president Michael Binder commented that the review team's findings demonstrate that the CNSC's regulations and good practices compare favourably with those of international counterparts. Our challenge, he said, is now to review the team's suggestions and recommendations and move forward in implementing improvements in a timely manner.

The IRRS peer review team will be producing a final report identifying good practices, suggestions and recommendations, which will be made public in the fall along with CNSC's management response.

More details are available on the CNSC and IAEA websites.

$150,000 for intervenors in Darlington new build EA

The Canadian Environmental Assessment Agency (CEAA) is making available $150,000 under its Participant Funding Program to assist groups or individuals in participating in the environmental assessment of the proposed Darlington New Nuclear Power Plant Project, located at the existing Darlington Nuclear site in the Municipality of Clarington near Oshawa, Ontario.

This funding is being made available to help successful applicants review the Environmental Impact Statement (EIS) that will be prepared by the proponent. The funding may also be used to prepare for and participate in the public hearings that will be announced at a later date by the panel.

A Funding Review Committee, independent of the environmental assessment process, will consider all applications and make a recommendation on the allocation of funds. The deadline for applications is July 20, 2009.

The *Participant Funding Program Guide*, the application form and the contribution agreement are available on the Agency's Web site at www.ceaa-acee.gc.ca.

CNSC to review Enhanced CANDU 6

The Canadian Nuclear Safety Commission (CNSC) has agreed to review the enhanced CANDU 6 reactor design of Atomic Energy of Canada Limited (AECL). Under the agreement, signed in mid May 2009, CNSC will conduct a high-level review of the EC6 design based on the Regulator's expectations set out in Regulatory Document RD-337 for new nuclear power plants in Canada.

The EC6 is a Generation III 740 MWe pressure tube reactor, designed to meet current robust international industry standards and public expectations for safe, reliable, environmentally friendly, nuclear power generation. The EC6 design is enhanced by the experience and feedback AECL has gained in the design, construction and operation of the 11 CANDU 6 plants operating in five countries worldwide.

According to AECL, the EC6 reactor has a projected annual performance factor of over 90%. This is based on the proven reliability of the global CANDU 6 fleet that has an average lifetime performance factor of 89%, ranking it as one of the world's top performing nuclear power reactors.

The CNSC is expected to complete the high-level compliance review by February 2010.

WANO celebrates 20th anniversary

The last week of May 2009 representatives of the member organizations of the world Association of Nuclear Operators (WANO) gathered in St. Petersburg, Russia to recognize the 20th anniversary of the founding of the organization.

The driving force to establish WANO was the Chernobyl nuclear plant accident and the determination of nuclear operators worldwide to ensure that such an accident should never happen again. Formally established in Moscow on 15 May 1989, WANO has since built a solid reputation for professionalism and excellence. Its ground-breaking programs have won widespread respect throughout the industry.

WANO unites all the companies in the world that operate a commercial nuclear power plant. Membership includes the operating companies of 447 nuclear plants in over 30 countries. It expects that membership will increase further as more countries turn to nuclear power as a sustainable source of electricity.

Looking to the future, WANO leaders are working with nuclear plant operators worldwide to ensure that the next 20 years continue to build on this record of achievement. With a nuclear revival underway, WANO is committed to helping ensure the future success of the industry through continued sharing, communication and mutual support on safety-related matters.

Tom Mitchell Appointed President And CEO of OPG

In early May, Ontario Power Generation (OPG) Board of Directors named **Tom Mitchell** as President and CEO, to take effect on July 1, 2009 following the retirement of Jim Hankinson, the current president and CEO. Mitchell is currently OPG's Chief Nuclear Officer.

In announcing the appointment Jake Epp, chair of the OPG Board said," Tom Mitchell has demonstrated strong leadership abilities, considerable talents in moving a complex business forward, solid knowledge of OPG and the challenges it faces, and the kind of values that make a good CEO".

Jim Hankinson was appointed to the Board of OPG in 2003, and was appointed President and CEO in 2005. Although he had planned to retire in 2008 the Board asked him to say for an additional year.

Tom Mitchell was appointed Chief Nuclear Officer in December 2006. He previously held the position of Senior Vice President, Pickering B, responsible for the operation of the four Pickering B units. He joined OPG in 2002 as Vice-President, Nuclear Operations and also has served as Site Vice-President and Senior Site Vice-President, Pickering B.

Mitchell has over 30 years of nuclear experience. Before joining OPG, he held the position of Vice-President of the Assistance Division of the Institute of Nuclear Power Operations (INPO) in Atlanta, Georgia. His 19-year career at INPO included assignments at the World Association of Nuclear Operators, Nuclear Electric in the United Kingdom and Peach Bottom Atomic Power Station, where he served as Manager of Operations Support, Director of Site Engineering, and Site Vice-President. The performance of the station during his tenure improved from being in a regulatory shutdown to a recognized leader in safe and reliable operation.

Wolsong 1 begins refurbishment

Wolsong unit 1 was shut down on April 1, 2009 for a major refurbishment including retubing.

The unit started operation on November 21, 1982, produced its first electricity on December 31 of that year and was declared "in-service" on April 22, 1983. At its shutdown it had a lifetime capacity factor of 86.3%. It was the second CANDU 6 unit to go into operation, after Point Lepreau, which is already into refurbishment.

In 2006, the official rating of Wolsong 1 was reduced from 678 MWe to 622 MWe primarily due to ageing of the pressure tubes.

Canada and Argentina sign agreement on radioactive sources

In mid June 2009, the Canadian Nuclear Safety Commission (CNSC) and the Autoridad Regulatoria Nuclear (ARN) of Argentina signed an Administrative Arrangement on harmonization of regulatory controls on the import and export of radioactive sources.

The Arrangement establishes measures to ensure that imports and exports of Category 1 and 2 radioactive sources between Argentina and Canada are conducted in a manner consistent with the requirements of the relevant codes and guides of the International Atomic Energy Agency (IAEA).

The CNSC consulted with Canadian industry representatives on the process. The first such "arrangement" to be signed was with the United States Nuclear Regulatory Commission. Similar Arrangements have been concluded with Colombia and Mexico.

Consultations have been held and draft arrangements developed

with Brazil and Italy. Negotiations are proceeding with Australia, Belgium, India, Japan, Thailand and the United Kingdom.

One waste site terminated, one chosen

USA "terminates", Sweden decides

The Yucca Mountain waste disposal project in the USA has been effectively terminated. The US Department of Energy cut the budget for the project to an amount to barely keep the office open.

The department's budget request stated: "All funding for the development of the Yucca Mountain facility would be eliminated, such as further land acquisition, transportation access and additional engineering." "The ...budget request...implements the Administration's decision to terminate the Yucca Mountain program while developing nuclear waste alternatives."

Meanwhile, in early June, the Swedish Nuclear Fuel and Waste Management Company (SKB) decided to select Forsmark as the site for the final repository for Sweden's spent nuclear fuel.

The next step is to put together the needed documentation to submit a licence application for constructing a safe repository for nuclear fuel in Forsmark.

All spent nuclear fuel from Swedish nuclear power plants will be disposed of in the final repository at a depth of nearly 500 metres in the crystalline bedrock.The Forsmark site offers rock at the repository level which is dry and has few fractures. These properties are of a major significance for long-term safety. Surface facilities will be constructed in the existing industrial area, which reduces the environmental impact and provides access to the infrastructure of the area.

SKB will now proceed to complete applications for permits that will be reviewed by the Swedish Radiation Safety Authority and the Environmental Court. The applications will be submitted in 2010 and include the environmental impact assessment and a safety analysis for a nuclear fuel repository in Forsmark.

Apart from the future nuclear fuel repository, the system for managing spent nuclear fuel will also include the existing interim storage facility in Oskarshamn, and an encapsulation plant adjacent to Clab for which SKB has already applied for a building permit.

The selection of the site is the result of close to 20 years of work during which SKB has conducted surveys throughout Sweden and feasibility studies in eight municipalities. These were followed by site investigations in Forsmark and Oskarshamn between 2002 to 2007.

CNS Annual General Meeting

The 12th Annual General Meeting of the Canadian Nuclear Society Inc.(since incorporation in 1998) was held in the Palliser Hotel in Calgary, Alberta with more than 60 members present. (This was the 32nd AGM since the CNS was formed in 1978.)

Secretary Prabhu Kundurpi quickly determined that there was a quorum and then referred to the Minutes of the 11th AGM held in Toronto, Ontario on June 3, 2008. These were quickly approved.

Jim Harvie, President for 2008 – 2009, spoke briefly about activities during his period of office, noting particularly process on the recommendations of the Task Force on restructuring and the Special Session of the extended Council held in January to discuss the future of the Society. "Being president of the CNS has been a great privilege", he said in closing his remarks.

Ed Hinchley presented the Treasurer's Report, which included the report from the auditors. Calendar year 2008 ended with an excess of revenue over expenditures of $56,831 even though a deficit had been forecast. The major difference was the revenue from the very successful Maintenance Conference for which Bill Schneider was the primary organizer. *(A copy of the Treasurer's Report is being mailed to all members with this issue of the CNS Bulletin.)*

Then followed several reports from the various CNS committees. Unfortunately, many forgot that the AGM dealt with calendar year 2008 and reported primarily recent activities. One report that did focus on 2008 was that for the very active Education and Communication Committee, which had been prepared by Bryan White but presented by Jeremy Whitlock. It is reprinted in this issue of the CNS Bulletin.

Ben Rouben reported that CNS membership at the end of 2008 was 1225 , the highest to date. He presented the following graph to show the monthly trend of membership over the past decade.

Morgan Brown reported on the updating of the CNS website which was begun in 2008 and is continuing. He also had a chart to show the number of visits to the site over the past few years,

He noted that the Internet Committee has been involved in building a new web site, having hired consultant Elmir Lekovic to build the site and change the look. Aside from its fresh look and improved search, event calendar and navigation capabilities, it has an entirely new structure "behind the scenes". It is now to be a database, with easier updating capabilities (using a web browser) by the web administrators. This should improve the ability of individuals to update the site without needing to know HTML.

This new web site also has improved features for the CNS member, including posting and editing your own CV ("profile") on line. There are also forums available for CNS members to discuss nuclear-related matters. Conference organizers, branch executives and the CNS Council will be able to have their own private forums

Jim Harvie (R), CNS president for 2008 – 2009, presents a gavel, the symbol of authority, to Eleodor (Dorin) Nichita, after his election as CNS president for 2009 – 2010 at the CNS Annual General Meeting in Calgary, Alberta, 1 June 2009.

Previous CNS president Eric Williams (L) presents a plaque to Jim Harvie commemorating his term as CNS president for 2008 – 2009 at the CNS Annual General Meeting in Calgary, Alberta, 1 June 2009.

for organizing events and discussing CNS matters.

The activity of Branches varies dramatically, Syed Zaidi noted. Several branches have very active programs of speakers while the Alberta Branch, which is still small in numbers, is very involved in the public debate in that province.

Finally, Past-President Eric Williams, who chaired the nomination committee, presented a slate of candidates for the Executive and Members at Large. When a call for nominations from the floor produced no response, the slate was declared elected by acclamation. (See the boxed list elsewhere in CNS News.

Concluding the meeting there was the formality of Jim Harvie, as retiring president, handing a gavel to Dorin Nichita as he assumes the position of president for the 2009 – 2010 period. (CNS operates fiscally on a calendar year but officers and council members serve from AGM to AGM, typically June to June.) This was followed by former president Dan Meneley presenting Jim Harvie with a plaque commemorating his year as President.

Message from new president

(The following is a slightly revised – by him – text of the remarks by ***Dorin Nichita*** *after being elected as the 2009 – 2010 president of the Canadian Nuclear Society at the Annual General Meeting in Calgary, Alberta, 1 June 2009.*

First, I would like to ask all of you to join me in giving warm thanks to our now past president, Jim Harvie, for his work and stewardship of CNS over the past year. Thank you, Jim!

We are all aware that things are happening in the nuclear industry. There is increased recognition of the fact that nuclear technology needs to play a larger role in electricity generation. There is also an increased awareness of the importance of nuclear technology in non-power applications, such as in medicine.

It is fair to say that we can expect an increased level of activity involving nuclear science and technology over the following years and we can expect the ranks of specialists involved in this field to swell. Our Society needs to adapt to keep up with this new reality.

A process has already been started to try to update the way our society works. It began with Bill Schneider, it was formalized in the report produced by Murray Stewart and Bob Hemmings and is now in the hands of the implementation task-force led by Eric Williams. My job in the coming year will be to oversee this transformation process and try to colour it with some of my own views of where the CNS should be going. In a way, my task could be described as bringing the CNS into the 21st century, and doing so gently, building on our current strengths.

It is my belief that the education role of CNS is paramount, so I expect that the Education and Communications Committee will become more prominent in the next year, with a corresponding increase in its expenditures. Education, of course, covers education of the public as well as that of students and professionals.

Thanks to the efforts of Bryan White's and others, the Geiger Counters for Schools initiative has been a great success, making an important contribution to high-school student education and helping to dispel some of the misconceptions and fear nuclear technology inspires. I propose to make this initiative into a permanent CNS program with continuous funding.

I woold like to expand our undergraduate scholarship initiative to include graduate scholarships and to make the scholarship program permanent with continuous funding.

Finally, I think the time has come to revive the idea of a CNS scientific journal. The Canadian nuclear industry has enough unique features to warrant its own journal. I also happen to know there are currently enough members of the Society willing to support this idea and to assemble an editorial board.

It is clear that I envisage some expansion of our activities. This will require additional funds on a continuous basis. Initiatives such as Geiger Counters for Schools and Undergraduate Scholarships have so far been funded as one-off projects, albeit repeatedly. It is time to put them on a more solid financial footing. To that end, I intend to submit, for Council's consideration, the creation of a fundraising committee, in charge of finding industrial sponsors to support worthy endeavours such as the two already mentioned, as well as future programs that we may develop.

With that, I look forward to working with the newly-elected Council and all members of the Society to advance the goals of the Canadian Nuclear Society: education and promotion of Canadian nuclear technology.

Eleodor (Dorin) Nichita

Economic Stimulation, the Environment, and Energy

In recent months our society and our media have been obsessed with the latest economic crisis, and with the efforts of governments, at all levels, to stimulate the economy, get our industries producing, and maintain employment for our workforce. However, there has been little discussion of the implications of all this economic stimulation on other important objectives, such as protection of the environment and the need for reliable, economic sources of energy.

The philosophy of ever-expanding consumption appears to be endorsed by all political parties, including those who purport to be environmentally-friendly. The efforts of Canada's socialist parties to form a coalition demanding a sufficiently large economic stimulus, and the subsequent decision of the governing Conservatives to create a large fiscal deficit, together with the provinces' eagerness to follow suit, is clear evidence of this support. And the approach appears to be endorsed, to a large degree, by the media and the public. The so-called Green Party

of Canada has been noticeably silent on the implications on environmental issues of this frenzy of government spending.

But surely we cannot isolate our considerations of economic stimuli from these other issues.

Perhaps the most significant impact is that true conservation, as a means of reducing our energy demands and protecting the environment, has essentially been taken off the table. The philosophy of today's society is that we must, at all costs, maintain or increase our levels of consumption in order to boost our economy. Anyone suggesting that we economize and try to consume less is considered anti-social or unpatriotic. This simply flies in the face of the idea that conservation is a solution to our environmental problems.

Of course, we may harvest some of the peripheral benefits of conservation by making our homes more energy efficient or by recycling some materials, or by fashionable but minor political gimmicks like banning incandescent light bulbs or idling vehicles, which have a trivial impact on the bigger picture.

However, the major potential conservation benefits, which could be achieved by substantially reducing unnecessary consumption, are no longer available. If we were to forego all the latest fads and fashions, and revert to a simpler life style where we would consume only the basic necessities plus a few carefully chosen luxuries, we could obviate the need for much of the energy and materials needed to produce and transport the unnecessary goods that we consume. Equally, we could eliminate the need for dealing with all the resulting wastes. But this is no longer an option.

In order to support our economy, Canadians must at least spend all of their incomes on consumer products. If we want to be truly patriotic, we should go a bit further and go into debt at the low rates that our governments have mandated, so that we can buy even more stuff. Living a frugal and environmentally-friendly lifestyle is no longer a socially-acceptable choice.

Smaller homes and urban densification are also likely to be non-starters in the current economic reality. Our homes must remain large or become even larger, in order to accommodate all the consumer goods that we are expected to purchase. They will probably have to be in expanding and sprawling suburbs where there is more area to accommodate our material goods. The space we need to park all those vehicles that we are supposed to purchase, in order to support our ailing automobile companies and their union contracts, does not exist in concentrated downtown communities.

Most of us recognize that our efforts to protect or improve the environment are not so much related to ourselves or our own futures, as to the legacy that we leave to future generations. However, this does not get any serious consideration by those demanding massive deficit spending from our governments.

It is a little paradoxical that people who abhor the thought of leaving relatively small quantities of nuclear "waste" to future generations to deal with seem quite comfortable with bequeathing billions of dollars of debt to those same generations. If my grandchildren were given the choice of dealing with a soccer field of contained and rather benign nuclear material, or paying substantially more taxes to pay off debts incurred by their grandparents, (or to bail out automobile manufacturers who probably went bankrupt before they were born), I suspect that it wouldn't take them long to decide which they'd prefer. But many of today's politicians and pseudo-environmentalists are appalled at the idea of the former while accepting the latter with equanimity.

How do our policies on energy relate to all this? Obviously, our increased consumption will demand that we continue to use energy at current or even greater levels. Fortunately, economic and environmental considerations push us in the same direction on this issue. From an economic viewpoint, it is better that we produce the goods we are to consume in our own province or community to create employment and customers with money to pay for the goods, while environmental considerations favour producing things locally to minimize the impacts of unnecessary transportation from more distant locations.

This implies that we should strive to produce adequate local supplies of energy at the lowest possible cost and with the least negative effect on the environment, so that we can attract manufacturing industries to locate here rather than elsewhere. We should be fostering the development of all non-polluting sources of energy in order to achieve this.

We should therefore be investing heavily in any remaining viable hydroelectric opportunities, and in any economic and reliable sources of renewable energy. However, since the only available large-scale source of economic and environmentally-benign base-load power is nuclear, we should be following the example of environmentally-progressive countries like France, and making major investments to increase the contribution of nuclear power to our energy supplies. Anyone who claims to be in favour of economic stimulation and environmental protection, but who opposes nuclear power, is in a logically inconsistent position.

Perhaps the above analysis is overly harsh or simplistic. However, it is surely evident that the issues of economic stimulation, environmental protection, and energy production are sufficiently inter-related that any discussion of one without consideration of the others is unrealistic and fails to recognize that decisions in any one of these areas has important implications on the others.

Jim Harvie

WiN –YGN "Professional Development Seminar

Cheryl Cottrill

Women in Nuclear (WiN)-Canada and North American Young Generation Nuclear (NA-YGN) joined to present a Professional Development Seminar on Sunday, May 31, in Calgary just before the opening of the CNS Annual Conference.

A number of "not so young" delegates joined the session, either to learn from their younger associates or to pass on some of their experience or both.

Susan Brissette, president of WiN Canada,welcomed everyone and then turned the podium over to Cheryl Cottrill, WiN's Executive Director, who chaired the event and opened it with a networking "game" that required everyone to match up with at least two others while learning some nuclear facts.

The seminar began with a rapid history lesson by Jeremy Whitlock who covered a century of Canadian nuclear research and development in half as many minutes. He was followed by

Jeremy Whitlock

Tracy Edwards

a short description of the fission process and other basic facts by Tracy Edwards.

Those "technical" presentations were augmented by several presentations on broader issues:

- Networking & Taking an Active Role in Your Career – Mark McIntyre
- Talking to the Government & Nuclear Energy Opportunities in Alberta – Albert Cooper
- Career Opportunities in the Nuclear Industry – Tracy Edwards and Cheryl Cottrill

After lunch a Workshop was held in which participants were asked – "Tell us what you would like to see from the nuclear industry".

The seminar closed with a presentation and workshop by Elise Herzig on "Tell Your Own Story".

Although organized and run by WiN Canada and NA-YGN, the event was sponsored by the Canadian Nuclear Society as an extension of its 30th Annual Conference.

Education & Communication Committee

Report to CNS Annual General Meeting #12

1. Education Activities

1.1 Sponsorships

In 2008, the CNS continued to provide support to the following organizations:

- The Deep River Science Academy, www.drsa.ca, $3500
- Scientists in School, www.scientistsinschool.ca, $2100
- Visions of Science Network for Learning, www.visionsofscience.ca, $2100

1.2 Science Teacher Conferences

The CNS ECC hosted a booth at the Science Teachers Association of Ontario Annual Conference November 13-15, 2008. The booth was staffed by volunteers from the CNS, and WiN Canada.

Doug De La Matter (retired high school science teacher) and Bryan White presented the new Ionising Radiation Workshop at the STAO Annual Conference in Toronto, and on the same day Peter Lang presented the workshop at the Alberta Teachers' Association Science Council Annual Conference in Calgary. The Alberta Branch sponsored a booth at the Calgary Conference.

A paper was presented on the Ionising Radiation Workshop

and the CNS Geiger donation program earlier this afternoon. The workshop presentation files and notes, and the list of schools that have received CNS Geiger kits are posted on the Education page of the CNS website.

1.3 Education Fund

Education Fund spending by the Branches of the CNS takes a variety of forms.

2008 Financial Year. Most did not spend on education.

- Chalk River, Essay, Poster Contests, Sci. Fair, $1500
- Golden Horseshoe, $1200
- Ottawa, Science Fair, $500
- Sheridan Park Science Fairs; Sponsorship, $3200
- Total – $6400

The CNA previously requested that the CNS return its contribution to the capital that supports the Education Fund. (Council has discontinued the Education Fund in 2009.)

Branches are encouraged to continue supporting education activities.

2. World Nuclear University

No applications were received for the CNS bursary to assist with attending the WNU session at Oxford this summer. (No applications were received for 2008.)

3. Undergraduate Scholarship Program

Adriaan Buijs of McMaster volunteered to lead the scholarship program for 2009. He has reported that four applications were received and the 2009 Undergraduate Scholarship have been awarded. In one case two students elected to share the award.

- Ahmed Jihad Zerouali: *Error propagation calculations in DRAGON*, École Polytechnique de Montréal; supervisor: Guy Marleau

• Bradford Holmes and Mohamed Geweida: *Neutronics Analysis of An Incorporated Thorium/Uranium Breeder Booster in CANDU*, UOIT; supervisors: Ben Rouben and Matt Kaye

4. Rutherford Documentary

Professor J. Campbell [of New Zealand] reports that the Rutherford documentary is completed to the level accorded by available funding (Episode 1 DVD complete and Episode 2 almost complete). Episode 3 requires more patron funding.

The CNS is the sole Canadian sponsor to date -- patron or otherwise. The ECC is exploring the possibility of Prof. Campbell visiting Canada later this year or early next year to do a speaker tour of branches (or otherwise) with Episode 1.

Bryan White for Jeremy Whitlock and Peter Lang

CNS 2009 – 2010 Council

Executive

President	Dorin Nichita UOIT
1st Vice President	Adriaan Buijs McMaster University
2nd Vice President	Frank Doyle CANDU Owners Group
Secretary	Prabhu Kundurpi Retired (OPG)
Treasurer	Eric Williams Retired (Bruce Power)
Past President	Jim Harvie Retired (CNSC)

Members at Large

Parvaiz Akhtar	Retired/Consultant
Blair Bromley	AECL -CRL
Pierre Girouard	AECL - SP
Ed Hinchley	Retired (AECL)
Krish Krishnan	Sankrish Consulting
Peter Lang	Air Canada
James Lévêque	Independent
Kris Mohan	Retired (AECL)
David Novog	McMaster University
Duane Pendergast	Computare
Jad Popovic	Retired (AECL)
John Roberts	CANTECH Associates
Ben Rouben	12 & 1 Consulting
Len Simpson	Retired (AECL)
Murray) Stewart	Stewart Advantage Consultants
Jeremy Whitlock	AECL
Mohamed) Younis	AMEC NSS
Syed Zaidi	Retired (NB Power)
Michael Stephens	AECL-CRL

Student Conference Winners

There were 24 papers presented in the 33rd CNS/CNA Student Conference that was embedded in the 2009 CNS Annual Conference held in Calgary, Alberta, May 31 to June 3, 2009.

According to Guy Marleau, coordinator of the Student Conference, all of the papers were of a high standard. As a consequence, choosing the winning papers was a difficult task. Nevertheless, the following awards were made and presented at the Wednesday luncheon.

Bachelor level: Polad Zahedi, University of Toronto
"Comparative Studies of Digital Controllers in CANDU Nuclear Power Plants" (Polad was not able to attend the award ceremony)

Masters level: David Hummel, McMaster University
"Study of Trace Depressurization Predictions for the Marviken Critical Flow Test"

Doctorate level: Kristy Erickson, University of Guelph
"Isotope Effects on Apparent and Partial Molar volumes of HCL, LiCI, and NaCI Measured in H_2O and D_2O from 250 C to 350 C and 14 MPa to 19 MPa"

Guy Marleau (L) presents Certificate to David Hummel for best paper at the Masters level in the 33rd CNS/CNA Student Conference in Calgary, June 3, 2009.

Kristy Erickson (L) accepts the Certificate from Guy Marleau for the best paper at the Doctorate level at the 33rd CNS/CNS Student Conference in Calgary, Alberta, June 3, 2009.

New Members

We would like to welcome the following new members, who have joined the CNS in the last few months, up to 2009 June 22.

Nous aimerions accueillir chaudement les nouveaux membres suivants, qui ont fait adhésion à la SNC ces derniers mois, jusqu'au 22 juin 2009.

Muhammad W. Agam, Carleton University
Glen Aitken, Mammoet Canada Eastern Ltd.
Mohammad Iqbal Ali, OPG
Heba Jamal Al-Sadi, UOIT
Walter Aolari
Bev Archibald, Schulz Piping Components Canada Inc.
Jeffrey Armstrong, AECL
William J. W. Armstrong, Carleton University
Narinder Baines, Promation Engineering Ltd.
Daniel Balboa, Carleton University
Fang Bao, McMaster University
Michael Binder, Canadian Nuclear Safety Commission
Daniel Brady, Natural Resources Canada
Jennifer Campbell, AECL
Glenna Carr, AECL
Alexander Chalyk, Passat LTD.
Zhong Cheng, AECL
Matthew Lee Chiasson, Carleton University
Dai-Hai Chung, Atomic Creative Technology Co., Ltd.
Jonathan Kiaro Cianci, Carleton University
Paul M. Comi, Babcock & Wilcox Canada Ltd.
Eric John Cornish, Carleton University
Cheryl Ann Cottrill, WiN-Canada
Larry Russell Crichlow, Carleton University
Adam George Cziraky, McMaster University
Aurora Dranga
Lloyd E.G. Dunn, AECL
Andrew B. Duplessis, Stantec Consulting
Justin David Ferraro, Carleton University
Colin Elliott Fisher, UOIT
Vincent C. Frisina, AECL - CRL
Charlene Rae Gillis, University of Calgary
Matthew R. Gorman, N.B. Power Nuclear
Wade A. Grant, Canadian Nuclear Safety Commission
Sahil Gupta, UOIT
Bhagwat Swaroop Gupta, S. G. Associates
Fady Habib, Carleton University
Kody Hammel, Carleton University
Jack B. Henderson, Netzsch Instruments, Inc.
Greg A. Hersak, AECL
Elise Herzig, Elise Herzig and Associates
Charles W. Hess, Tetra Tech
James Eric Hilbig, JH Consulting
James Hine, Carleton University
David Holden, MarShield - Div. of Mars Metal Co.
Byron House, Bruce Power
Ross Hunter, Carleton University
Zarley Hutt, Carleton University
Brian M. Ikeda, UOIT
Michael Ivanco, AECL
Gobind Khiani, A.R.Thomson Group
Beverly Ann Kidd, AECL
Maxim Kinakin, UOIT
Vlad Y. Korolevych, AECL
Rohith Kosaraju, UOIT
Rishi Kumar, Global Technologies+Manufacturing Inc.
Ali Ladhani, UOIT
Luke Simon Lebel, Royal Military College of Canada
Brittany Leblanc, Carleton University
Arnaud Lejemble, KAEFER Canada Inc.
Blake Leontowicz, Carleton University
Kenneth Leung, McMaster University
Jeremy Licht, AECL
Roger Lounsbury, Suretech Development Limited
David Luxat, AMEC NSS
Jonathan Meehan
Travis Menard, Carleton University
Sheldon F. Merkosky, Hitachi Canada Ltd.
Ron Moleschi, SNC-Lavalin Nuclear Inc.
Bill B. Moriarty, Bruce Power
David Morikawa, Promation Engineering Ltd.
Seyed Mortazavi-Ravari, Carleton University
Aba N. Mortley, Royal Military College of Canada
Ian Morton, Crossby Dewar Inc.
Yasuhiro Nakashima, Hitachi Canada Ltd.
Dino Oliveira, SNC Lavalin Nuclear
Francesca Ottoni, SNC-Lavalin Nuclear Inc.
Philippe Paquette, Bruce Power
Eve-Lyne Pelletier, EACL
Aurelio Fajardo Perez, UOIT
Christopher N. Persaud, UOIT
Matthew Pilecki, UOIT
Taite Purnell, Hitachi Canada Ltd.
Nael Qashua, UOIT
Kevin Radey, Carleton University
Hamidullah Rahimy, UOIT
Chary Rangacharyulu, Universtiy of Saskatchewan
Mirza Rayman, Hatch Ltd.
Sanaz R-Ghias, York University
William R. Robinson, Ontario Power Generation
David Rodgers, Kinectrics
David J. Rowan, AECL
Andreas Rudolph, Kinectrics Inc.
Nasim Sabet-Sharghi, Carleton University
Arash Sajadi, Hatch Ltd.
Mouna Saoudi, AECL
Carmen Scribner, Carleton University
Ramin Shafagh
Babak Shakeri-Rad
Anthony Sibik, Westinghouse Electric Company
Elena Sorin, OPG - Pickering
Christian Surette, Carleton University
Justin Symons, UOIT
Garima Takyar, Carleton University
Jennifer A. Tapp, Algonquin College
Robert Taylor, Kiewit Power, Inc.
Colette E. Taylor, AECL
Jeroen Thompson, McMaster University
Kenneth Thompson, Moeller Electric Inc.
Ryan Tinafar, Carleton University
Sovuth Try, Carleton University
Arun Veeramany, University of Waterloo
Robert L. Walker, Ontario Power Generation
Brad R. Wilson
Victoria Wodzak, Ontario Power Generation
Adam Woods, UOIT
Igor Yakubtsov, AECL
Rabi Omer Yari, UOIT
Frank Yee, AECL
Emad Yousuf, Carleton University
Jin Yu, UOIT

6TH CNS International Steam Generator Conference

November 8 -11, 2009

Hilton Toronto
Toronto, Ontario, Canada

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- Chemistry Control
- Thermalhydraulic Performance
- Life Management Strategies

Abstracts

Deadline: June 19, 2009 NEW

Abstracts: see **www.cns-snc.ca**

Registration: see **www.cns-snc.ca**

www.cns-snc.ca

CALENDAR

2009

July 12-17 — **Twelfth Quadrennial International Conference on Fracture (ICF12)**
Ottawa, Ontario
website: http://www.icf12.com

July 20-24 — **Win Global & U.S. Women in Nuclear Conference**
Washington, D.C.
website: http://register.nei.org

Aug. 9-14 — **SMiRT 20 Conference Int'l Assoc. for Sturctural Mechanics in Reactor Technology**
Espoo, Finland
website: iasmirt.org

Aug. 31-Sept. 4 — **World Nuclear University Forum**
Manchester, England
website: world-nuclear-university.org

Sept. 24-Oct. 1 — **TPeaceful Uses of Atomic Energy Conference**
New Delhi, India
website:
http://sites.google.com/site/peacefulatom2009
or: www.ins.india.org

Oct. 11-15 — **12th International Conference on Environmental Remediation and Radioactive Waste Management**
Liverpool, England
website: www.icemconf.com

Nov. 8-11 — **6th International CANDU Steam Generator Conference**
Toronto, Ontario
website: www.cns-snc.ca

Nov. 15-19 — **ANS Winter Meeting & Nuclear Technology Expo**
Washington, D.C.
website: www.new.ans.org/meetings/m_64

2010

Feb. ?? — **CNA Annual Conference and Tradeshow**
Ottawa, Ontario
website: www.cna.ca

May 9-14 — **PHYSOR 2010, "Advances in Reactor Physics to Power the Nuclear Renaissance"**
Pittsburgh, PA, USA
website: http://www.physor2010.org

May 30-June 2 — **31st Annual Conference of the Canadian Nuclear Society and 34th CNS/CNA Student Conference**
Montréal, Québec
website: www.cns-snc.ca

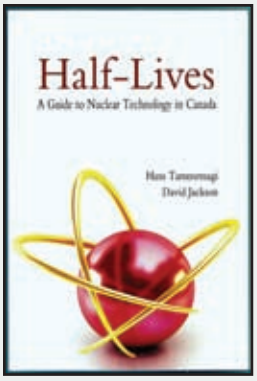
June 13-17 — **ANS Annual Meeting**
San Diego, CA, USA
http://www.ans.org/meetings

Sept. 26-29 — **DD&R 2010 International Meeting on Decommissioning, Decontamination and Re-Utilization**
website: www.ans.org

Oct 3-10 — **International Conference on Water Chemistry of Nuclear Reactor Systems (NPC 2010)**
(organized by CNS)
Québec City, QC;
website: http://www.cns-snc.ca

Oct 24-30 — **17th Pacific Basin Nuclear Conference**
Cancun, Mexico
website: www.pbnc2010.org.mx

BOOK REVIEW



Half-Lives – a guide to nuclear technology in Canada

Hans Tammenagi & David Jackson

Oxford University Press,
Don Mills, Ontario 2009
ISBN 978-0-19-543152-0

This book is really an up-dated version of one by the same authors, published in 2002 under the name *Unlocking the Atom*. That does not make it any the less valuable, in fact the re-issue attests to the value of the material provided.. To quote from the book's jacket: *The uses of nuclear technology in Canada are explored in clear, accessible language, from uranium mining to electricity-producing nuclear power reactors, to nuclear medicine and industrial applications.*

The first chapter includes a short history of nuclear science and technology in Canada that all those involved should read. Overall, the book provides a concise but complete overview of the many aspects of nuclear science and technology in Canada.

Eau Lourde, It's Heavy Water!

by Jeremy Whitlock

I'm sitting here with a very special guest, the 2000 Megawatt Man. Welcome sir.

Merci.

Okay, 2000 megawatts. That's a lot of megawatts. Tell me, what's it like having that many megawatts?

Well you know, it's a bit embarrassing to be this… how you say… fantastic, you know. We have a lot of megawatts, this is true, and we can build this anywhere on the planet. We are very, very big.

I understand. And you want to build big reactors in Canada?

Oui, this is true. But we are not new to Canada, you know. We have been here for forty years.

Well, okay. Some of the companies you have acquired have been here that long, yes.

This is what I have said. And you know, we like Canadians as well. They are very funny people. We love your Jerry Lewis.

He's not Canadian. Perhaps you mean William Shatner?

Oui that is him. He is very funny.

Okay. And so, you have big reactors to build in Canada?

Yes they are very big. And you know, we are building two of them right now in Finland and France, and they are very big indeed.

Everything is going well?

Magnifique. Of course, they are first-of-a-kind, so they are of course behind schedule. But everyone who builds a new reactor will be, as you know, behind schedule for the first time, and so we are the first to be behind schedule and that is our advantage.

I see. And do you think Canadians have any advantage because they have never stopped building reactors around the world, unlike other vendors including yourself?

But the new Canadian reactor is first-of-a-kind, and so you see it is no advantage, and it is silly to say so I think.

Well not really. But anyway, so you have these very big reactors…

Very big, yes.

Yes, and so do you feel they will be more attractive to Canadian utilities than the CANDU design?

But of course. Because you know this is not about nationalism anymore; this is about business, and in this new business you see that state-owned technology plays no preference in the decision. The traditional advantage of state ownership over the private sector is, how you say, "les nouvelles d'hier"?

"State-owned", like your own? Your country is ready to consider CANDUs then?

Pardon… I don't understand? Oh, did I mention that we have been in Canada for forty years?

Yes you did. Okay, so you don't feel that Canadians will prefer the advantages of heavy water technology over light water.

Heavy water! What is this… heavy water? It is a silly thing. Heavy water. Oh please, I can't lift this water, it is too heavy! Where is the heavy water – is it at the bottom of the ocean? Help, I don't understand this water – it is too heavy for me!…

Are you mocking heavy water?

But of course not. One can only mock what is serious in the first place, and this heavy water is very silly. If it had a mouth it would laugh at itself.

I see. Some people say heavy water reactors have certain advantages over light water reactors. Simpler supply chain, inherent safety, flexible fuel cycles, localization of manufacturing, more control and experience with aging issues.

Aging issues! What is this "aging issues"? We, you know, offer a 60-year plant that does not need refurbishment.

Really? Sixty years of operation and no major maintenance?

I did not say that, of course, but we don't need refurbishment. It is not even in our vocabulary.

But, um, "refurbishment" does mean major maintenance. You know, to address aging issues. You don't see a need for this with your design?

Pardon… I don't understand? Did I mention yet that heavy water reactors have proliferation issues?

Well, that's not really true. They're no more proliferation-prone than light water reactors.

They make plutonium.

Like light-water reactors…

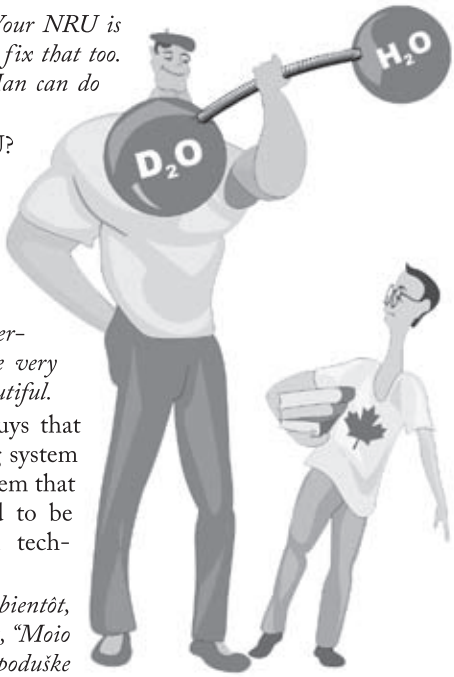
But in higher concentration.

No, actually about half. But look, do you not feel Canadians will want to protect the nuclear industry they paid billions to develop over 60 years?

But there is a flea in that thinking. There will of course be a Canadian nuclear industry, regardless of the reactor design. Somebody will have to clean our floors and get my coffee.

What about the design and engineering, the major supply chain, not to mention the R&D infrastructure…

Ah, yes, the R&D. Your NRU is a bit leaky, no? We can fix that too. The 2000 Megawatt Man can do 120 megawatts.



You can fix our NRU? What do you know about the NRU?

I know it's not heavy water! Ha ha.

Er, it *is* heavy water.

Pardon… I don't understand. Our reactors are very big you know. And beautiful.

Hey wasn't it you guys that supplied the processing system for MAPLE? The system that never worked and had to be replaced by Canadian technology?

Okay, I have to go. A bientôt, and as they say in Russia, "Moio sudno na vozdušnoy poduške polno ugrey!"

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