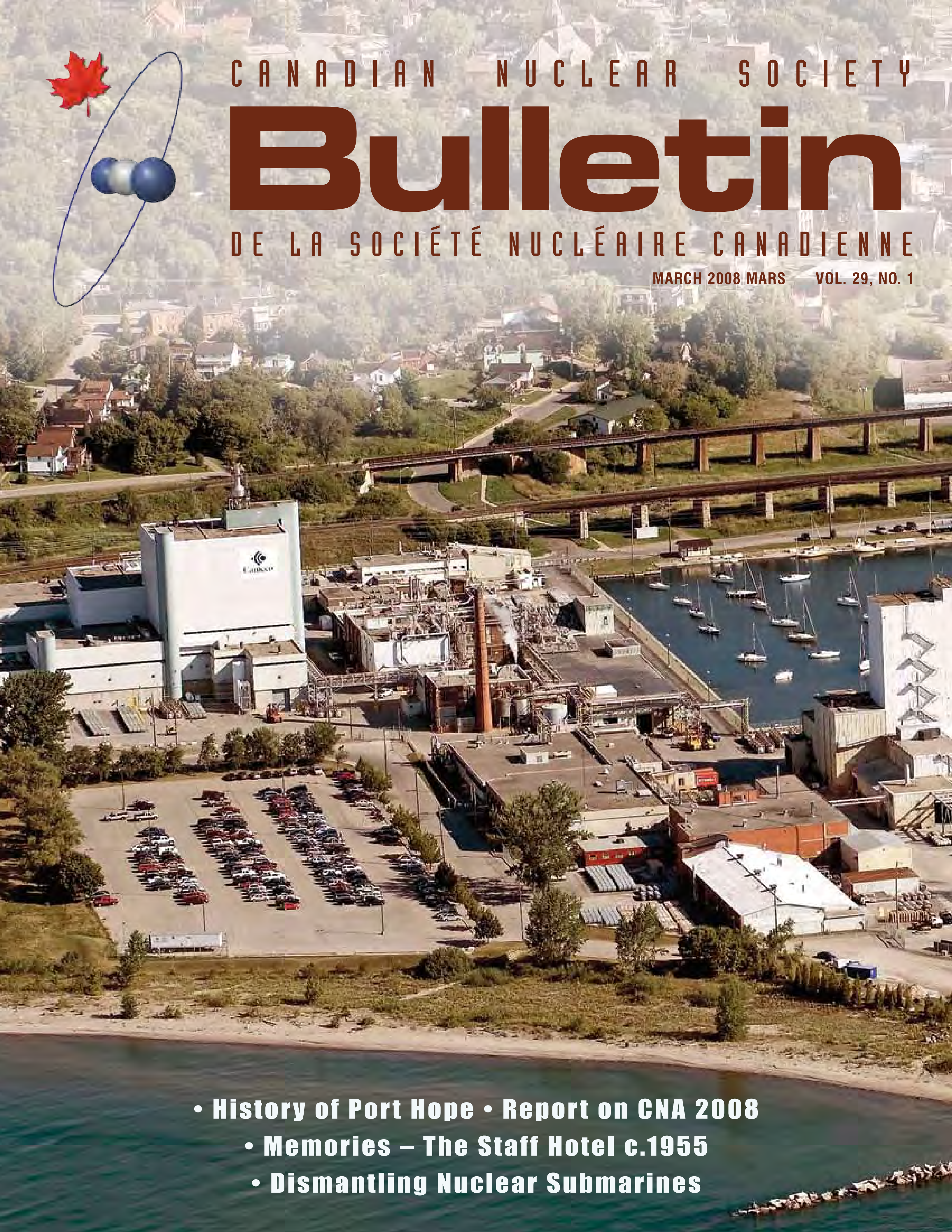

CANADIAN NUCLEAR SOCIETY

Bulletin

DE LA SOCIÉTÉ NUCLÉAIRE CANADIENNE

MARCH 2008 MARS VOL. 29, NO. 1

• History of Port Hope • Report on CNA 2008

• Memories – The Staff Hotel c.1955

• Dismantling Nuclear Submarines

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They're Back!

For two decades they were hiding, lurking in dark corners, waiting patiently, and now that new nuclear build is in the air, they're back. They're everywhere. They are those coercive utopians that have a social agenda that cannot be sold with only true truth. They dispense doubt and anxiety using scare tactics, camouflaged with a veneer of truth. They are weapons of mass disruption.

The Port Hope Community Health Concerns Committee, using funds raised at local bake sales, sponsored the Uranium Medical Research Centre's laboratory in Germany to test nine local residents, seven of whom who were suffering from various unexplained illnesses including cancer. They presented their results at a "peer-reviewed" conference in Denmark [only the abstract underwent peer review, and no paper was delivered – it was a poster session with handouts at the conference]. With such a thin veneer of truth they scared newspaper readers with the headline "**Town's Residents Test Positive For Uranium Contamination**", and later scared TV watchers featuring a shocking film of a childless swing swaying in the breeze with **Cameco** in the background, reporting "**Port Hope Tests Show Radioactive Contamination**".

As if this wasn't a sufficient fear factor, they augmented the anxiety through the media by linking Port Hope's uranium facility to the Manhattan Project, the nuclear bombs dropped on Japan and continuing supply of depleted uranium to make armour-piercing missiles used in Afghanistan. The veneer of truth is that the urine analysis techniques are well established – the analysis results are indisputable. Scary?

Look behind the veneer and find out. ***Everyone*** is "contaminated" with radioactive uranium! Furthermore, ***not*** everyone is in ailing health.

According to Health Canada, the general population in North America have uranium concentrations in urine samples that range from 3 – 60 ng/L. Drinking water is the predominant source of uranium with well-water having higher levels than lakes. The nine Port Hope residents (four worked at Cameco) ranged from 2.1 to 23.4 ng/L.

Unfortunately, it took a few days for Health Canada's response to get to the media. So with much ado about nothing these coercive utopians evoked fear and anxiety, harming the Port Hope community in many ways. The nine residents with unexplained ailments thought they had an "explanation" (i.e. someone to blame); a million dollar real estate deal went south; a local convention was cancelled; Cameco's image was tarnished; the CNSC was accused of not fulfilling its regulatory mandate; and indeed, the entire industry was affected in some way.

CNS members have a potent "bug-spray" to ward off these coercive utopians. The bug-spray is the scientific knowledge of experts who can deliver truth in full, in context, and in a timely manner. No veneer required.

In This Issue

The last edition of the **CNS Bulletin** (December 2007) focussing on **NRU** was planned well ahead of a bizarre series of events unprecedented in Canadian History. Since there has been a flood of letters and media attention, we decided not to comment further; instead, **Fred Boyd** has produced a brief chronology of the events leading up to **The NRU Isotope Affair** from around 1990 to present.

More proof that the nuclear renaissance is alive and well comes from the record attendance at the **CNA Nuclear Industry Seminar** last month in Ottawa. **Fred Boyd** reviews the seminar as well as the embedded 5th meeting of **WiN**. There has also been some significant industry development in Ontario, Alberta and at Bruce Power.

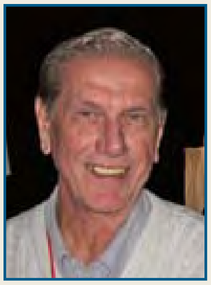
The recent Ontario Government's RFP was sent to four international nuclear power plant vendors, which prompted two contributed articles. **Donald Jones** has provided an easy-to-follow guide to the four reactor designs, and **Bill Schneider** has provided his personal opinions on what would be needed for a successful CANDU bid.

In Alberta, the nuclear debate is heating up while Bruce Power has completed its transaction with Energy Alberta and Bruce Power Alberta has submitted an application for a site licence in that province for up to four ACR 1000 CANDU nuclear reactors. See "Letters to the Editor" and "General News".

Also in this issue **Jim Arsenault** writes on the history of the **Port Hope** refineries from the 1930s while **Al Bancroft** shares memories of the AECL **Staff Hotel** in the 1950s and plans for an upcoming reunion.

There are three technical papers, Fred Boyd's regular **General News** and **CNS News** (which includes **Eric Williams' President's Report** and last but never least is **Jeremy Whitlock's Endpoint**, which gives an extended metaphorical perspective of a time not so long ago and in a land not so far away.

Comments and letters are always welcome.



Changes at the CNS

The CNS now has grown to over 1200 members and that growth brings challenges. To better handle the increased activity of the Society, a task force of Murray Stewart and Bob Hemming reviewed the organization and prepared a proposal for moving forward. That was discussed at the February 22, 2008 Council meeting and another task group is reviewing comments from Council members. *(See the President's note in the CNS News section.)* It is likely that the Society will follow the lead of most other similar organizations and engage an "executive director" to manage day to day affairs. The future of the Bulletin was not explicitly addressed except that the Publications Board proposed last year should definitely be established. (Are you interested?)

The NRU – isotope imbroglio

If you need to look it up "imbroglio" means a "complicated, confused, embarrassing situation", which I thought aptly describes the events of November to February concerning the shutdown of the NRU reactor and the resulting near crisis of medical diagnostic isotopes. No one and no organization came out looking well. There were: conflicting communications, vacillating decisions, stubbornness, arrogance, and political happenings bordering on theatrical drama.

One positive outcome was that the media, the public, and, most importantly, the prime minister, became aware of our nuclear activities. When, a few weeks later, the federal government budgeted $300 million for Atomic Energy of Canada Limited, there was hardly any comment. A year earlier that would have drawn screams of criticism. Hopefully, AECL will use some of that money to actually complete the design of ACR 1000 in time for the Ontario decision.

Other steps forward were the actions by the interim president of the Canadian Nuclear Safety Commission to restart the pre-licensing review of ACR 1000 and to participate in a joint review of the NRU affair with AECL.

Ontario call for proposals

The invitation by the Ontario government for bids on new nuclear power plants *(see General News)* can be considered both good and bad news. The good is that it has finally decided to move on the nuclear issue, which is an integral part of rebuilding Ontario's electricity generation capacity. The bad, from the perspective of someone who has spent a lifetime in the Canadian nuclear program, is the total absence of recognition of what has been achieved in this country over the past half century.

Starting from scratch during the Second World War, Canada developed an indigenous program of nuclear research and development that resulted in Nobel winning scientific discoveries, a world-class radioisotope business, and a distinctive and successful design of nuclear power plants. Ontario, through its utility Ontario Hydro, was very much a part of this successful program.

Yes, the people of Ontario deserve the value of competition but the potential of throwing away all of that historical investment is disheartening.

Since the federal government funded our early nuclear research and development many of us believe it should take steps to protect its investment, beyond its recent budget support for AECL.

CNSC design rules

Unheralded and largely unnoticed was the issuance last fall by the CNSC of its draft regulatory document, RD 337, "Design of New Nuclear Power Plants". The stated intent was to be technically neutral and to generally conform with international recommendations. For that last point reference was made to, and many sections based on, a document of the International Atomic Energy Agency, NS-R-1 "Safety of Nuclear Power Plants: Design", issued in 2000.

In response to its invitation to comment CNSC received many critical comments from key players.

The joint submission from the nuclear utilities (in which Westinghouse said it participated) and that from Areva focussed particularly on clause 8.4.1, which states, in part: *The design shall provide two redundant, separate, independent and diverse means of shutting down the reactor.* The utilities complained that it could severely limit their choice of design. Of course, LWR designs do not provide that redundancy.

That requirement was one of the first rules set by the Atomic Energy Control Board (predecessor of the CNSC) and I was intimately involved in its development. Long before PSAs became feasible it was our means of achieving the target of 10^{-6} per reactor year for a significant release of fission products. About the same time, the USA began to worry about ATWS (anticipated transient without scram) and continued to do so, without resolution, for more than a decade. Now the LWR designers claim they can show, by PSA, that a single shutdown system combined with the control system can achieve the same goal. Being skeptical about PSAs at that level of improbability I hope CNSC retains that clause.

(The CNSC has posted the comments on its website and invites comments on them.)

Fred Boyd

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~ Cover Photo ~

Cameco plant at Port Hope.

– Photograph courtesy of Cameco Corporation.

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CNS provides Canadians interested in nuclear energy with a forum for technical discussion. For membership information, contact the CNS office, a member of the Council, or local branch executive. Membership fee for new members is $80 annually, $47.00 for retirees, free to qualified students.

La SNC procure aux Canadiens intéressés à l'énergie nucléaire un forum où ilf peuvent participer à des discussions de nature technique. Pour tous renseignements concerant les inscriptions, veuillez bein entrer en contact avec le bureau de la SNC, les membres du Counseil ou les responsables locaux. Les frais annuels d'adhésion pour nouveaux membres sont 80$, 47$ pour les retraites, et sans frais pour les étudiants.

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CNA Nuclear Industry Seminar 2008

Record attendance; New format at annual event

by Fred Boyd

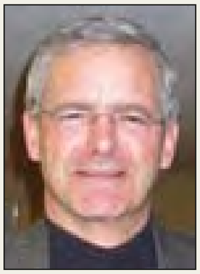
With the theme, *Going the Distance: Nuclear Energy in the New Age*, the 2008 version of the annual Canadian Nuclear Association's *Nuclear Industry Seminar* drew a record attendance of over 650 to the Westin Hotel in Ottawa for its new one and a half day format, 28 and 29 February 2008.

Principal organizer, CNA's Director of Communications, Claudia Lemieux, assembled an eclectic group of presenters, including: a former astronaut; the head of Ontario's distribution organization; two speakers with diametrically opposing views on climate change; a pollster; a columnist; a bureaucrat; and a provincial minister. The only traditional views from the industry were on uranium mining and waste management.

The seminar was preceded by an extensive reception on the evening of February 27. **Gary Lunn,** Minister of Natural Resource Canada, gave a welcoming address in which he expressed his strong support for the Canadian nuclear program. He particularly noted the $300 million in the recent federal budget for Atomic Energy of Canada Limited to support the completion of the ACR 1000 design and improve facilities at its Chalk River Laboratories. *(A condensed version of his speech is printed elsewhere in this issue.)* Lunn was thanked by **Hugh MacDiarmid**, recently appointed president and CEO of Atomic Energy of Canada Limited, the sponsors of the reception.

Murray Elston, president of the CNA, opened the seminar proper the next morning. In his usual easy style he welcomed everyone, referred to the 85 students attending sponsored by Ontario Power generation and Wardrop Engineering, greeted visitors from the Ukraine, and referred to the many sponsors, who, he emphasized, made the Seminar possible.

He then turned the stage over to **Pierre Charlebois,** Executive Vice President, Ontario Power Generation, and Chairman of the CNA. "The Canadian nuclear industry is in a stronger position than it has ever been", Charlebois stated, noting its safety record, excellent performance, and environmental benefits. "The nuclear renaissance is here", he added. Nevertheless, there are challenges, he said, particularly finding and developing the people capable of building, operating and maintaining our nuclear facilities. In closing, he acknowledged the important role of the regulator, the Canadian Nuclear Safety Commission.



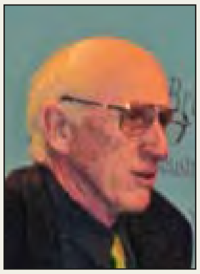
Lead speaker was **Marc Garneau**, Canada's first astronaut and former president of the Canadian Space Agency, whose theme was *Our Changing Planet: A Growing Role for Nuclear Among Energy Resources.* "I consider myself an environmentalist but have not always been so", he commented. His first space flight in 1984 changed him forever, he added.

After a short description of the preparation for, and an actual flight he showed some dramatic photographs from space, illustrating environmental problems such as deforestation in Brazil and Madagascar, smog and dust in China, and retreating glaciers in different parts of the globe.

We need energy, he stated, it brings us wealth but also pollution, largely because more than 80% of our primary energy comes from burning fossil fuels. Proposals to combat that include: conservation, increased efficiency, and "renewable" sources. Each has its challenges, he said. While nuclear fusion offers a promise in the future, nuclear fission is available now. But there are public concerns that must be addressed, he emphasized.

Next was **Marwan Masri**, recently appointed President of the Canadian Energy Research Institute, who spoke on W*orld Energy: the Past and Possible Futures.* He emphasized at the beginning that his talk was about the global energy scene, not nuclear. With the aid of a large number of slides he covered world energy consumption and supply, the relationship between energy and environment, some alternative world energy futures, and the outlook for North America. The most recent report from the International Energy Agency shows that fossil fuels are likely to continue to be the dominant energy source for decades.

Turning to the practical problem of delivering electricity, **Laura Formosa**, President and CEO of Hydro One (owner and operator of Ontario's electricity distribution system), spoke about the many challenges her organization faces. Like generation plants, the building of transmission lines is an extensive process with long lead-times, she noted. It is essential to work cooperatively with the public, she added, and commented that particular collaboration is needed with First Nations groups whose reservations lie in the path of proposed lines. Hydro One hopes to have a new line to Bruce completed in 2011. She closed by noting that there are major challenges, particularly dealing with an aging workforce and loss of domestic suppliers.

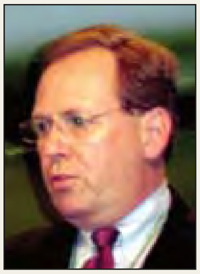


At the excellent lunch sponsored by Areva Canada, **Stewart Brand**, a noted environmentalist and author of the *Whole Life Catalogue*, spoke on *The Greening of Nuclear Power*. He commented that his attitude towards nuclear changed after seeing the Al Gore movie *An Inconvenient Truth* and added that he accepted the conclusion of the fourth report of the International Panel on Climate Change that mankind's actions are a significant factor in climate change. Noting several "greens" who now support or accept the role of nuclear power, he commented, "David Suzuki needs to change his mind". He added that he believed the young generation is looking at nuclear with "fresh eyes".

In the first address of the afternoon session, titled *Climate Change: What Is It All About?* (a change from that in the program), **Robert Reinstein**, President of the consulting company Reinstein & Associates International, presented a different view of the IPCC and its report. After noting that the IPCC reports to the United Nations Environment Program and the World Meteorological Organization he reviewed briefly the history since 1992 and the several "Conferences of the Parties" (CoP). It was at CoP 3 in Kyoto in 1997 that the "Kyoto Protocol" was conceived.

He then turned to the recent IPCC report #4 which confirmed the global warming trend and stated those involved had 90% confidence that human activity was the primary cause. Reinstein asserted that in the detailed studies, as contrasted to the summary "political" report, that there are many caveats concerning: weak models, inability to explain long-term trends, limited acknowledgement of solar variability, and lack of understanding of indirect effects of radiation.

Environment has become the new religion, he claimed, aided by a media that is not objective. We have to face the reality of: continuing increase of emissions; economic growth; population growth; transportation demand; and others, he stated. In closing, he recommended that, in the "beyond 2012" Kyoto discussions, Canada should side with the USA, Russia, China and India that each country should decide its own mix of commitments.



Then, as a change of pace for the last presentation of the day, **John Wright**, Senior V. P. Ipsos-Reid (a polling company) presented the results of his company's recent polls on nuclear in a talk titled, *Staying ahead of the Curve – what Canadians think About Nuclear"*. He began by stating support for nuclear was up, somewhat, in all provinces, with 67% in favour of refurbishing existing nuclear power plants and 48% in favour of new plants. Despite the extensive news coverage of the NRU – isotope affair of December and January, only 40% indicated that they had heard about it. "Energy" is not a high public concern, he noted, with only 11% placing it at the top of their list.

A reception in the exhibition area provided a pleasant way to end the day and continue the "networking" which was very evident. It was not clear whether or not the crowded situation abetted or inhibited that process.

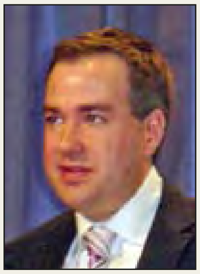
Friday morning began with a breakfast, sponsored by GE-Hitachi Nuclear Canada, at which **Jeffrey Simpson**, national affairs columnist with the Globe and Mail, offered his views in a talk entitled *Hot Air: Meeting Canada's Climate Change Challenge.*

He said that, although he was not sure why, climate change is high on the public's consciousness. Canada's emissions [of greenhouse gases] are only 2% of the world total, he noted, and compared Canada's situation to that of China where a new coal-fired plant is added every week. He then added that we have not used that argument in other arenas to avoid action. Nevertheless, he stated, Canada's record against its Kyoto commitment is the worst in the world, with the exception of Spain.

This is an emission problem, not an energy one, he stated. We must put a price on CO_2 emissions, he said, and applauded British Columbia for creating a carbon tax. He compared that to Alberta's proposal for greater "intensity" which, he said, will not change its position as being the worst emitter in the western world.

He then did a quick survey of some other countries, such as the new policy in the UK favouring nuclear and the major proposals in the USA. Finland, he said, has the most successful and logical program, building new nuclear plants and proceeding with a waste repository. Turning to Ontario, he commented that citizens still remember the debt from Darlington and added that the Ontario government must make its decision about new plants on price and product, not nationalism.

Next was a presentation on two topics: *Nuclear Fuel Supply into the Future* and the *Global Nuclear Energy Partnership*, by **Ken Seitz**, Vice-President, Cameco Corporation. He began with on overview of the role of uranium compared to other fuels for the production of electricity. First, using USA figures, the percentages of electricity production cost of different fuels are: uranium 26%, coal 77%, natural gas 92%. Another comparison, again using US data, the fuel production costs in cents per kilowatt-hour are: nuclear 1.7; coal 2.4; gas 6.7; oil 9.6.



Currently, he noted, Canada and Australia combined produce half of the world's uranium while only a minor percentage of fossil fuels come from what he described as "politically stable" countries. However, significant uranium resources have been found in a number of countries. The demand over the next two decades is estimated at about 4 1/2 billion pounds of U_3O_8 while the reasonably assured and inferred resources total 12 billion. If' "speculative" resources are added the total becomes 38 billion. Almost as an aside he mentioned that there are now more than 400 junior uranium exploration companies working in Saskatchewan.

Turning to "value added" in the various steps of producing fuel for light-water reactors, he said mining is 31%; conversion 8%; enrichment 47%; manufacturing 14%. Clearly, he noted, there is an opportunity for Canada in enrichment and stated that the current government moratorium must not be extended.

Seitz then addressed his other subject, the Global Nuclear Energy Partnership (GNEP). Begun by the USA two years ago, he stated that the objectives of GNEP are to:

- develop a new generation of nuclear reactors which are more secure
- develop reliable fuel supplies
- eliminate proliferation
- minimize waste

Canada joined GNEP in late 2007. To a question he stated that Canada had only signed onto broad principles, details are still being discussed.

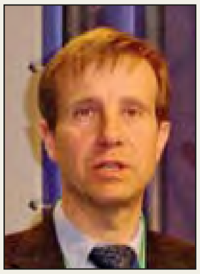
Following on fuel related issues, there was a panel discussion on the topic *Advances in Social Aspects of Nuclear Waste Management*, chaired by **Ken Nash**, President of the Nuclear Waste Management Organization (NWMO) with participants:

- **Kathryn Shaver**, NWMO
- **Tom Issacs**, Lawrence Livermore National Laboratory, USA
- **Claudio Pescatore**, OECD Nuclear Energy Agency

Shaver began with a brief review of NWMO's extensive program for public consultation and referred to the recommendation for an "Adaptive Phased Management" approach, which was endorsed by the federal government last year.. Over the next four years NWMO intends to: continue its relationships; advance research; address issues of financial security; develop a governance structure; build an implementation structure; and develop a process for site selection.

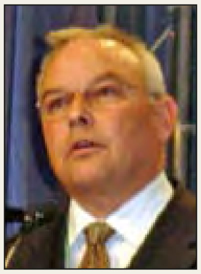
Repeating the claim that spent nuclear fuel is dangerous for hundreds of thousands of years, Isaacs noted that there had been a consensus for decades that geologic disposal was the best solution. He praised Finland for actually proceeding with a repository, claiming that a major reason for the continuing debate over the Yucca Mountain facility in the USA was because there had been no public involvement.

Pescatore agreed that public participation was essential. We are in a new world, he said, with everyone connected, where everyone can comment. Referring to recent actions of the OECD Nuclear Energy Agency to involve the public, he stated that "collective action is here to stay".



Under the title, *Shaping Ontario's Nuclear Generating Future*, **Peter Wallace**, Deputy Minister, Ontario Ministry of Energy, reviewed the past and current situation in the province. He began by noting that after many decades of public ownership of electricity generation and distribution the system was changed dramatically a decade ago. However, the new arrangement did not work well and now the province has a mixed arrangement. "Climate change" is politically in vogue, he acknowledged, and that affects electricity policy. The Ontario government's direction to the Ontario Power Authority to develop a 20-year plan included the condition to maintain, at least, the nuclear component.

There is still the intention to shut down the coal fired plants by 2015, he said. Conservation and natural gas fuelled stations for peak loads are exoected to cover the loss of the coal generation. Saying that nuclear is needed, studies are underway of refurbishment or new build. He referred to a consultant's study of economic benefits underway and added that both Ontario Power Generation and Bruce Power have been asked to evaluate different nuclear technologies. Decisions will be made this year, he stated.



The final speaker of the Seminar was **Jack Keir**, Minister of Energy, New Brunswick. He began by stating, "We have a vision of New Brunswick being an 'energy hub' for the Maritime provinces and New England states". This includes a LNG terminal, new refinery, extended gas pipeline and a second nuclear power plant. In addition there are plans to build a centre of technical and engineering excellence. To a question he stated that they had chosen to go with "Team CANDU" because of the many side benefits and the fact that Team CANDU will take the financial risk.

CNA's Murray Elston took the stage to close the event. Before doing so he named the members of the CNA staff, who, he said, did all the work in organizing the Seminar: Claudia Lemieux, Sanela Turkanovic, Matthew Foster, Kate Sarsfield. He thanked those attending and invited them to stay for a closing buffet lunch.

The long list of sponsors were: Ontario Power Generation; Atomic Energy of Canada Limited; Areva Canada; Power Workers' Union; Wardrop; Bruce Power; GE-Hitachi; Cameco; E.S.Fox; The Society of Energy Professionals; Babcock & Wilcox Canada; Newman Hattersley; Aecon; MDS Nordion; Hydro Québec; L3 Communications; Merlin General; McMaster University; SNC-Lavalin Nuclear; Ian Martin; Hatch, Sargent Lundy; NWMO; MDA; Hitachi; MarShield; RCM Technologies; Kinectrics; Canadian Nuclear Society.

Gary Lunn, Minister of Natural Resources Canada,(R) shakes hands with Hugh MacDiarmid, recently appointed president of Atomic Energy of Canada Limited, at the opening reception of the Canadian Nuclear Association's 2008 Nuclear Industry Seminar, 27 February 2008, in Ottawa, while Murray Elston, CNA president, looks on. Photo courtesy of CNA

Minister supports nuclear

Following are excerpts from the address by Gary Lunn, Minister of Natural Resources Canada, at the opening reception of the Canadian Nuclear Association's 2008 Nuclear Industry Seminar in Ottawa, 27 February 2008.

It is my pleasure to be here tonight to open your conference and discuss our government's vision for your industry and your path forward.

I strongly believe that nuclear will play a critical role in developing a clean energy future for Canada.

In yesterday's budget we made a substantial, targeted investment in key technologies. We have announced that we're investing $250 million for the world's first clean coal project that's fully integrated with CO_2 technology.

We are also investing $300 million to support nuclear energy. These funds will support the ongoing development of the ACR and ensure AECL has the capacity to maintain safe, reliable operations at its Chalk River Laboratories. Nuclear power generation is safe, it's clean, and it's emission-free. It's based on Canadian technology, and it's using a Canadian resource. I can't think of a better way to demonstrate our confidence in Canada's nuclear industry.

When we talk about nuclear issues, we have to look at the impact of the prolonged shutdown of the NRU this past December. This challenge drew much attention to the nuclear industry in Canada. For the first time in a long while, Canadians are actively engaged in thinking about where Canada's nuclear industry is going.

The government of Canada has serious responsibilities where nuclear is concerned — responsibilities both to your industry and to all Canadians. [The] $300 million that we're committing to AECL in the budget is the next important step to realizing our four key objectives.

- First and foremost, maintaining the safe and secure operation of the existing fleet.
- Second, ensuring that nuclear power continues to be a viable option in Canada's electricity mix.
- Third, ensuring that Canada's industry has a maximum opportunity to benefit from the global expansion and the use of nuclear energy and nuclear technologies.
- Finally, we must be effective, responsible and accountable managers of the federal investment in nuclear technology.

Safety and security are the responsibility of the operator but we also require an independent regulator to hold industry to the highest standards. We need a regulatory process that's efficient. Investors have to know the rules of the game. That's the job of the Canadian Nuclear Safety Commission.

The government has its own responsibilities for safety. We provided $45 million this fiscal year to ensure that Chalk River Laboratories can meet all of its CNSC regulatory requirements. New funds committed in yesterday's budget will add to that figure.

I've introduced a new and long overdue Nuclear Liability and Compensation Act, which will bring the cap of the liability of nuclear operators up to modern-day standards again and bring clarity to the rules.

In order to ensure that nuclear energy remains a viable and a growing energy option, we must address the public concerns around nuclear power. This is why, since becoming the Minister of Natural Resources, I have accepted the Adaptive Phase Management Plan recommended by the Nuclear Waste Management Organization. As well, one of my first actions as the Minister of Natural Resources was to announce over $500 million for AECL to deal with its legacy liabilities.

When it comes to maximizing the opportunity for Canada's nuclear industry, we need to be clear on the role that AECL will play. With the ongoing consolidation and vertical integration of the global industry, we have to consider all the options for the future structure of AECL.

I have launched a review of the corporation and appointed a new CEO and chair of the board for AECL. There's been a lot of speculation where this review may lead. I can only say that all the options are on the table.

ACR is a key element. Not just for AECL but for every single one of you involved in Canada's nuclear power industry. We want the technology to succeed and we want to help AECL to be in a position of strength, to seize the opportunities in front of it

Through our past and ongoing investments, we have built a unique national asset and helped to create an industry that has the potential to be a major player. I am committed to creating the conditions that will allow this industry to build on that strength in the future.

There is more to be done. I have outlined what our government is doing, now it's your turn to seize the moment.

To capitalize on this opportunity you have to cultivate an environment where Canadians look to nuclear power to create clean power. You also have to manage your corporate reputation. I believe this is essential.

With some of the country's brightest and most innovative individuals I have no doubt that you will rise to this challenge. You can count on my support to work with you.

WiN Canada celebrates 5th birthday

Women in Nuclear Canada celebrated its 5th birthday with an all-day conference in Ottawa on February 27, 2008, immediately prior to the annual Seminar of the Canadian Nuclear Association. The theme was *"Celebrating Excellence"*. Well over 100 women and a few men attended the event, which was held in the Ottawa Congress Centre.

The previous day a fortunate twenty-five delegates participated in a tour of the Chalk River Laboratories of Atomic Energy of Canada Limited located about 200 km. northwest of Ottawa. The tour, sponsored by AECL, provided the participants with an insight into the many activities conducted at the laboratories.

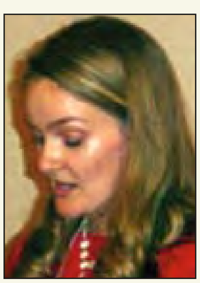
The conference began with a welcome from WiN Canada president, **Susan Brissette** followed by a short "icebreaker session" to encourage attendees to get to know each other.

Then she introduced **Deborah Gills**, Vice-President, Catalyst Canada, who began a morning-long workshop with a presentation on the challenges women face in the nuclear workplace introduced by a presentation by Gills titled her talk *Women in Business: Myths and Realities*.

Her first Myth was: since women make up close to half of the workforce it is only a matter of time before they rise to the top! The reality, she pointed out, is that "women have not reached the corner office". Further, she noted, in the electrical industry women account for over 25% of the workforce but account for only 6% of the combined trades, engineering and management. Another myth, she noted, is that moving up is all about merit – gender is irrelevant. In reality, she contended, men and women face different barriers.

The business case for diversity is compelling, she stated, noting, among other things, that companies with more women in management are, statistically, more successful based on return on investment.

Following her presentation those attending broke into groups to discuss to discuss the myths she presented and propose actions that would help the nuclear industry improve its policies towards women. Helping to facilitate discussion were eight senior Human Resource representatives from major companies associated with the Canadian nuclear program. WiN Canada intends to prepare a paper based on the recommendations and strategies developed that will provide the nuclear industry with ideas to attract, select, retain and engage more women in its workforce.



At lunch, **Tracy Edwards**, of Bruce Power, spoke about her two-year secondment to the Nuclear Energy Division of Natural Resource Canada (NRCan). She began by mentioning her involvement with the Young Generation Nuclear organization and in environmental activities which had been factors leading to the secondment opportunity. Working on policy and political issues is completely different from a technical job such as she had at Bruce, she stated. Much of her time over the first year and a half of her secondment was related to Canada's position regarding the Global Nuclear Energy Partnership. Canada signed onto the international program last fall. She closed by recommending such a secondment to anyone who had the opportunity.

After brief reports from the several WiN Canada chapters, most of the afternoon was taken up with a series of concise (8 minute) presentations, by representatives of the chapters, on different "best practices".

On behalf of the Durham Chapter, **Colleen Walker,** from DTE Energy – Fermi 2, spoke on the topic "Achieving Alignment on key improvement initiatives". This involves identification of the initiatives, communicating them with all staff, monitoring progress and celebrating achievements. She stated that when staff have a good understanding of the desired improvements they can make it happen.

Michelle Brough, of Bruce Power, representing the Bruce Chapter, described the detailed work of Bruce Power's dedicated motor starter maintenance facility where she works, which involves careful dismantling, cleaning and refurbishing the various parts. They have refurbished over 900 breakers, which has saved the company over $6 million in avoided loss time.

Representing Eastern Ontario, **Joan Miller**, from AECL Chalk River Laboratories, spoke about "CRL Best Practices – Our strength is our people". That is an old cliché, she admitted, but has proven to be true. They are striving for world-class performance in all areas – with "no compromise".

Germaine Watts, of New Brunswick Power, Pont Lepreau, represented the New Brunswick Chapter with a talk on "Organizational Culture Inventory". Through a "Team-Based Resourcing" program the company has a strategy for filling vacancies internally. She noted that over 30% of the Point Lepreau staff will be eligible for retirement within 5 to 7 years and it will be a challenge to maintain their high safety culture.

Last in the chapter presentations was **Jennifer Noronha**, of Ontario Power Generation, Pickering A, representing the Golden Horseshoe Chapter. Her topic was "Ownership and Use of the Human Performance Simulator" which is being used to train on event prevention tools. She commented that women are much more aware of "human factors" than men.

Then, **Cheryl McCulloch,** of Bruce Power, spoke about WANO (World Association of Nuclear Operators) and her participation in a WANO team review of the Cernavoda 1 plant in Romania.

This was followed by "guided tour" of the impressive new WiN Canada website, by **Cheryl Cottrill**, who was appointed full-time Executive Director of the organization in mid 2007. The URL is: www.wincanada.org.

Susan Brissette closed the conference with a few remarks on speaking to groups, networking and communication.

WiN Canada continues to grow, its membership is now 565 and its annual meetings reflect this. The structure of the 2008 conference was different than previous ones but appeared to engage those attending and promises to leave a message from the morning workshop about gender issues in the workplace. One tradition was followed – a photo of the entire group, taken during the afternoon break. As might be expected lunch was a healthy soup and salad affair. But, at the afternoon break, there was a huge chocolate cake, to celebrate the 5th anniversary, which was swiftly devoured!

Report by Fred Boyd

The members of the 2008 WiN Canada Board of Directors pose with the 5th anniversary cake during the 2008 WiN Conference in Ottawa, 27 February 2008.
Back – L to R – Janet Donegan, Chair WiN-Durham; Cheryl McCulloch, Bruce Power; Yvette Amor, Babcock & Wilcox; Parva Alavi, AECL
Front – L to R – Bernice Lanigan, Chair WiN-New Brunswick; Barbara Goetz, Co-Chair WiN-Bruce; Susan Brissette, WiN-Canada President; Cheryl Cottrill, Executive Director WiN-Canada; Tracy Gagne, Chair WiN-Eastern Ontario and Judy Tamm, Chair WiN-Golden Horseshoe West.

Photo courtesy of WiN Canada

A view of most of the attendees at the 5th WiN Canada Conference, in Ottawa, 27 February 2008

Photo courtesy of WiN Canada

The NRU – isotope affair by Fred Boyd

From mid November 2007 to mid February 2008 the word "nuclear" was in the media daily. When a routine shutdown of the NRU reactor at the Chalk River Laboratories of Atomic Energy of Canada Limited was extended following a regulatory dispute the supply of a radioisotope widely used in medical diagnosis was threatened. That led to a bizarre series of events that saw a special sitting of Parliament, a rapid piece of legislation, the firing of the chief nuclear regulator, and new appointments at AECL.

While most readers of the CNS Bulletin probably followed this story we decided to offer a concise chronological summary rather than comment on it. If nothing else the saga brought Canada's nuclear program to the attention of the public and to the highest levels of government.

Background

NRU is a 50-year-old research reactor used for: (1) engineering research, development and demonstration of fuel and materials for CANDU nuclear power plants; (2) a source of neutrons for advanced research; and (3) production of medical radioisotopes. Of direct application to the event is the production of molybdenum 99, a short life radioisotope whose radioactive decay daughter, the very short life technetium 99m is a widely used medical diagnostic tool.

Preamble

mid 1990s	AECL – CRL plans seven safety-related upgrades for the NRU reactor that include two backup pumps seismically qualified for anticipated earthquakes.
May 2000	With the coming into force of the new Nuclear Safety and Control Act, the Canadian Nuclear Safety Commission (CNSC) succeeds the Atomic Energy Control Board as the nuclear regulator.
Oct. 2000	AECL submits an updated Safety Report for NRU based on the upgrades, some of which were yet to be installed.
Dec. 2005	AECL reports that all upgrades installed.
June 2006	CNSC grants a licence renewal for NRU until 2011.
Mar. 2007	AECL submits a further update of the NRU Safety Report.

Event

5 Nov 2007	CNSC staff at CRL discover seismically qualified motor starters for the backup pumps not installed.
16 Nov 2007	AECL informs CNSC that NRU is operating within its "safety envelope"
19 Nov 2007	NRU begins scheduled maintenance shutdown.
21 Nov 2007	On learning of concerns of CNSC staff, AECL decides to extend shutdown and informs MDS Nordion, the company that processes the Mo 99 for medical use.
22 Nov 2007	Date MDS Nordion said it informed Natural Resources Canada and AECL that an extended shutdown would result in a serious worldwide shortage of the radioisotope.
27 Nov 2007	AECL requests acceptance of just one seismically qualified pump.
29 Nov 2007	CNSC rejects proposal.
2 Dec 2007	AECL informs CNSC (and MDS Nordion, NRCan) it will keep reactor shutdown with consequential loss of production of Mo 99.
3 Dec 2007	Date Minister of Natural Resources (minister responsible for AECL and through whom CNSC reports) said he became aware of radioisotope problem.
5 Dec 2007	Date Minister of Health said he became aware of radioisotope problem.
7 Dec 2007	AECL again proposes one pump arrangement and requests CNSC ruling by Dec. 11. No response from CNSC
11 Dec 2007	Federal government instructs CNSC to take into account isotope situation. Later introduces Bill C-38, which strips CNSC authority over NRU for 120 days. After all day emergency hearing bill is passed.
12 Dec 2007	Bill C-38 becomes law.
14 Dec 2007	One of main pumps connected to emergency power supply through seismically qualified motor starter.
16 Dec 2007	NRU restarted at 3:44 a.m.

18 Dec 2007 Radioisotope shipments recommence

27 Dec 2007 Gary Lunn, Minister of Natural Resources Canada, writes Linda Keen, President of the CNSC expressing "deep concern" about her actions and doubt that she possesses the required judgement.

8 Jan 2008 Keen replies rejecting accusations and accuses Minister of interfering with an independent regulatory authority.

9 Jan 2008 CNSC includes update of situation at a previously scheduled public Meeting (not Hearing). CNSC staff present a review since Dec. 6 (previous Meeting). Lawyer on behalf of AECL tables letter pointing out inconsistencies of correspondence between AECL and CNSC staff.

15 Jan 2008 Keen fired as President but remains a Commissioner. (Commissioners appointed for fixed term, one of whom named as President)

16 Jan 2008 Michael Binder, formerly Associate Deputy Minister at Industry Canada, named Commissioner and interim President of CNSC

29 Jan 2008 Keen appears before HoC Natural Resources Committee and states NRU was 1,000 times less safe than current standards. AECL posts note on its website that this was erroneous and misleading.

27 Jan 2008 NRU shut down for another maintenance during which second pump connected to seismically qualified electrical supply.

2 Feb 2008 NRU restarts.

14 Feb 2008 CNSC and AECL announce joint review.

18 Feb 2008 Brian McGee, Sr. V.P. and Chief Nuclear Officer at AECL – CRL announces he will leave in May 2008

Related item

14 Dec 2007 Hugh MacDiarmid named CEO of AECL. Glenna Carr named chair of Board.

11 Feb 2008 Government announcement inviting applications for position of President of CNSC.

Preliminary Announcement and Call for Papers

OECD NUCLEAR ENERGY AGENCY

CSNI Workshop on

"Ageing Management of Thick Walled Concrete Structures, including ISI, maintenance and repair – Instrumentation methods and Safety Assessment in view of long term operation"

Hosted by Nuclear Research Institute Rez
Prague – Czech Republic
October 1 – 3, 2008

Deadline for Abstracts (200 – 400 words):
On-line abstract submittal form – April 30, 2008

Notification of Accepted Papers:
May 30, 2008

Deadline for Full Paper Submission and Registration:
On-line registration form – September 5, 2008

On-line information and registration are available
www.nea.fr/html/nsd/calendar.html

Ric Fluke
Editor, CNS Bulletin

Dear Editor,

The editorial in the CNS Bulletin of December 2007 asks whether our regulator is in focus. It's one thing to say, "This is outrageous!" when you weigh the risk of hypothetical harm from the small amount of radioactivity released in the postulated NRU accident, of very low probability, against the certain benefit of medical radioisotopes for 160,000 patients per month. But what will you say after I point out that such hypothetical harm has actually been demonstrated to be a health benefit?

In the draft Canadian regulatory document for new nuclear power plants [1], Section 4.4.1 indicates dose acceptance criteria of 0.5 mSv for anticipated operational occurrences and 20 mSv for design basis accidents. Wouldn't you expect these very important safety limits to be based on sound scientific and medical evidence?

Because the release of radioiodine is a key limit in nuclear reactor safety, let's examine a recent publication on its use in medicine. Radioiodine is used increasingly as the first-line therapy for hyperthyroidism, having been employed for this purpose for more than 60 years. Because of the on-going concerns about the subsequent risk of cancer, a population-based cohort study was carried out at the University of Birmingham in the UK [2]. The cohort included 7417 patients, who were treated between 1950 and 1991. Significant decreases in overall cancer incidence (0.83, 95% CI = 0.77-0.90) and mortality (0.90, CI = 0.82-0.98) were observed. "The decrease in overall cancer incidence and mortality in those treated with for hyperthyroidism with radioiodine is reassuring."

What makes this study so remarkable is the very large iodine-131 dose given to the patients: Mean (SD) = 308 (232) MBq. A hyperthyroid European person treated with I-131 (sodium iodide) receives a total body dose of 180 microGy/MBq and a thyroid dose of 1,000,000 microGy/MBq [3]. These patients received a mean total body dose of 55 mGy and a mean thyroid dose of 308,000 mGy. This Birmingham study demonstrates convincingly that a decrease in cancer incidence can be expected. Other studies have not confirmed an increase.

So what do you say about our regulatory document, which specifies a dose limit of only 20 mSv for design basis accidents, when we have an approved medical treatment, used world wide for 60 years, that gives a mean dose of 55 mSv and results in a decrease in cancer incidence?

You might ask, "What about the thyroid cancers that were attributed to the radioiodine that was released in the Chernobyl accident?" I asked Zbigniew Jaworowski MD, a former chairman of UNSCEAR, this same question with reference to a recent HPS paper [4]. His reply, summarized in the appendix below, suggests that we have been grossly misled.

I'm sure we all recognize that it will be very difficult to convince the ICRP to change its 50-year policy of issuing radiation protection recommendations that are based on invalid assumptions [5]. These recommendations only magnify public fears, delay projects and increase their costs.

In light of the approaching nuclear renaissance, isn't it time to have regulatory documents that are based on reality? We should be taking effective action to prepare Canadian regulatory standards that are based on radiobiological science and realistic risk assessments.

Jerry Cuttler

References:

1. CNSC draft regulatory document, "Design of New Nuclear Power Plants," RD-337, October 2007
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3. Roedler HD, Kaul A and Hine GJ, "Internal Radiation Dose in Diagnostic Nuclear Medicine," Verlag H. Hoffman (Berlin) 1978, pp111
4. Ron E, "Thyroid Cancer Incidence Among People Living in Areas Contaminated by Radiation from the Chernobyl Accident," Health Physics **93**(5), November 2007, pp502-511
5. Mitchel REJ, "Cancer and Low Dose Responses in Vivo: Implications for Radiation Protection," Dose-Response **5**, 2007, pp284-291, see also CNS Bulletin **27**(4), December 2006, pp23-26

Appendix

Remarks by Dr. Jaworowski on thyroid cancers reported following the Chernobyl accident

1. The effect of better reporting, heightened awareness and screening may be a cause of the observed increase of thyroid cancer in Belarus and not an effect of radiation. A decade ago, during a screening program in the USA, the incidence of thyroid cancers and of nodules was 7 and 17 times higher (respectively) than before screening. This is the same as the increase seen in Belarus. Screening is mentioned eight times in the paper [5], but tied to thyroid cancer only three times:
   - "Extremely brief time period between radiation exposure and thyroid cancer diagnosis is striking and had not been documented previously." (Actually, UNSCEAR 2000, Vol. II, p. 544, Table 57, in Russia, the first high increase in thyroid cancer incidence, 9.1 cases in 100,000 children,

occurred in 1987, one year after exposure, against all previous knowledge that suggested about 30 year latency). Yet the paper [5] states: "Whether the short latency ... is related to ... early detection screening ... is unclear."

- "Because increased medical surveillance and early detection screening were introduced after the accident, comparison of thyroid cancer incidence before and after the accident can be misleading."
- Quoting the work of Ivanov's et al, the paper [5] states: "These results suggest that the increased cancer rates in Bryansk compared with general population rates are due to thyroid cancer screening and better reporting rather than radiation exposure." This is supported by the fact the thyroid cancers incidence was lower in the highly contaminated Bryansk region than in the general population of Russia.

2. Any serious work on Chernobyl thyroid cancers should discuss the problem of occult thyroid cancers, which is directly related to the effect of the enormous screening programs being carried out in the contaminated areas (up to 90% of children are screened every year!). The paper [5] does not mention a single paper from a rich literature on occult thyroid cancers, the incidence of which is much higher than the incidence of the "Chernobyl cancers" (Franssila and Harach, 1986; Furmanchuk, 1993; Furmanchuk et al., 1993; Gerasimov, 1991; Harach et al., 1985; Moosa and Mazzaferri, 1997; Tan and Gharib, 1997).
3. The paper does not mention the Scandinavian studies showing that iodine-131 used in high doses for diagnostics and therapy did not resulted in an increase, but in decrease of thyroid cancer incidence (Hall et al., 1996; Holm et al., 1991; Holm et al., 1988).
4. The abstract states: "Twenty years after the accident, excess thyroid cancers are still occurring ... we can expect an excess of radiation-associated thyroid cancers for several more decades." The summary concludes: "Further research also is needed" and a "Long-term follow-up of Chernobyl-exposed populations." Such invocations for support of this author's type of studies are frequent in this author's papers and in similar papers.

Ed. Note. The nuclear debate is going strong in Alberta, and given recent announcements in Ontario, we expect to see a lot more "experts" criticising nuclear energy. Below is a letter to the Peace River Record Gazette, a good example of how CNS members who are actual experts, can get involved with the debate.

Letter to the Editor – Peace River Record Gazette

Tuesday February 12, 2008

Dear Editor,

The recent discussion of "bias" in the nuclear debate misses the crucial point that bias is something all of us have, without exception. Bias is not a dirty word, but a culmination of experiences that inform every thought each of us entertains. The problem is not the existence of bias, but recognizing and dealing with it when objective decisions are called for.

The field of science, for example, operates on the fundamental principle of overcoming bias to make decisions based solely on objective evidence. Professional scientists are not only trained to think this way, but are also held accountable to this ideal through peer review. Bias is, however, only one aspect of the "credibility issue" that Albertans must contend with as opinions and facts on all sides of the nuclear debate flood their collective consciousness. Another aspect is professional expertise and this has unfortunately been maligned in the current debate as well.

Willingness and ability to speak on the nuclear topic and quantity of information supplied, should not be confused with professional expertise. Likewise, educational background, while an indication of technical aptitude or even intelligence, should not be confused with expertise in a specific and unrelated area. For example, it may come as a surprise to many that nuclear physics has little to do with nuclear power reactors (other than sharing the "n" word), and someone with a degree in this area is no more qualified to discuss nuclear reactors than an aerospace engineer or a biochemist. Likewise, nuclear grass-roots critics, no matter how eloquent, dedicated, popular, educated, or willing to be flown to Alberta, are not experts on this topic. Moreover, when they leave Alberta they are absolutely unaccountable for the statements and fear they leave behind. This is further confused when such non-experts present a resume of past appearances before inquires and committees, often as an "expert witness" or similar designation. As well-read and often long-time activists against nuclear power, these people do deserve to be heard in such processes, just as Albertans are free to invite whomever they want to share their opinions on the topic. But they are not experts in the sense of word that should be of interest to those seeking the truth.

Without question, CANDU nuclear technology is owned by all Canadians and it is crucial that all voices in this debate be heard, but it is also crucial to know whom you are listening to. When I speak to Albertans, for example, I do so as a professional expert, a scientist, and a father with a young family in a small rural town next door to Canada's largest nuclear laboratory. To suggest that I might mislead the public (and by implication also my family) through the bias of my employment is an insult not only to myself but to the thousands of Albertans who deserve to hear the facts behind this successful, but controversial, made-in-Canada technology.

Jeremy Whitlock,
Atomic Energy of Canada Ltd.
Past-president, Canadian Nuclear Society

New Nuclear Power Plants for Ontario by Donald Jones, AECL (Retired)

Ed. Note. *The following article was submitted by Donald Jones. It provides a concise review of the four contenders invited by the Ontario Government to submit proposals for new build.*

Towards the end of this year the Ontario government will select the technology for its future nuclear power plants. To clarify the differences between the contending reactors I have put together the following quick overview.

Ontario's requirement is for a stand-alone two-unit nuclear power plant to provide around 2,000 to 3,500 MWe of baseload generating capacity at a site to be specified with an option for one or two additional units. It is likely that the first units will be located at either the Darlington site near Bowmanville or the Bruce site near Kincardine. However the output from the Bruce site is presently transmission constrained. All nuclear-electric generation in Ontario comes from Atomic Energy of Canada Limited's (AECL) CANDU reactors at Pickering, Darlington and Bruce.

The contenders are, AECL's 1085 MWe (net) ACR-1000 (Advanced CANDU Reactor), Westinghouse Electric Company's 1117 MWe (net) AP1000 (Advanced Passive), AREVA NP's 1600 MWe (net) U.S. EPR (United States Evolutionary Pressurized Reactor) and the 1550 MWe (net) GE Hitachi Nuclear Energy's ESBWR (Economic and Simplified Boiling Water Reactor). Westinghouse has Toshiba as a majority shareholder, AREVA has the government of France as a majority shareholder and GE-Hitachi has GE as the major shareholder. AECL is a federal crown corporation and is part of Team CANDU consisting of Babcock and Wilcox Canada, GE-Hitachi Nuclear Energy Canada Inc., Hitachi Canada Limited and SNC-Lavalin Nuclear Inc.

Generally the engineering split in Team CANDU would be, AECL, Mississauga, Ontario, responsible for the design of the nuclear steam plant including reactor and safety systems; Babcock and Wilcox Canada, Cambridge, Ontario, responsible for supply of the steam generators and other pressure retaining components; GE- Hitachi Nuclear Energy Canada Inc., Peterborough, Ontario for the fuel handling equipment; Hitachi Canada Limited, Mississauga, for the balance of plant steam to electricity conversion equipment, and SNC-Lavalin Nuclear Inc. in Mississauga, Ontario, for the balance of nuclear steam plant.

ACR-1000 Description

The ACR-1000 uses heavy water as a moderator and light (ordinary) water as a coolant. The circulating light water is heated under pressure in the reactor and the heat is transferred to boilers, called steam generators, where steam is produced and piped to the turbine-generator system outside the reactor building where the electricity is generated. The reactor itself consists of a horizontal steel cylinder (calandria) filled with heavy water at near atmospheric pressure and temperature, which acts as a moderator to slow down the neutrons and enable the nuclear reaction to take place. Tubes, or channels, that contain the uranium fuel pass through the calandria in the axial direction and connections are made at both ends so that light water at high pressure can pass through and take away the heat from the nuclear reaction. Fuelling machines at each end of the reactor can select any of the channels and replace used, or damaged, fuel with fresh fuel while at full power. The ACR-1000 uses fuel that is low enriched to around 2 percent uranium - 235. Previous CANDU reactors in Canada and around the world used natural uranium fuel (0.7 percent uranium - 235) and thus required heavy water to be used as the coolant.

AP1000, U.S. EPR and ESBWR Description

The AP1000, the U.S. EPR and the ESBWR are light water reactors (LWRs). The AP1000 and U.S. EPR are pressurized water reactors (PWRs). The nuclear reaction takes place in a thick walled steel vessel that contains fuel strings that are left inside until they need to be replaced, usually every 12 to 24 months. The reactor has to be shutdown for around three weeks for this to take place. Light water, as in the ACR-1000, is pumped through the vessel at high pressure to remove the heat and transfer it to boilers that produce steam for the turbine - generator. The conventional part of the PWR power plant, that is, the electricity generating part outside the reactor building, is generally the same as the ACR. The PWR fuel needs enrichment to around 5 percent uranium - 235.

The ESBWR is a boiling water reactor (BWR). The ESBWR does not have boilers like the ACR and PWR; the steam is produced directly in the reactor vessel itself. This means that the steam in the turbine outside the reactor building is radioactive so shielding will be required around the turbine during operation and radiological protection will be necessary during maintenance. It requires a shutdown to replace used or damaged fuel just like the PWR and uses fuel enriched to 4.2 percent uranium - 235.

Reference Plants

The ACR-1000 is based on the CANDU 6 pressurized heavy water reactors (PHWRs) operating in New Brunswick (Point Lepreau), Quebec (Gentilly Unit 2), South Korea (Wolsong Units 1 to 4), Argentina (Embalse), China (Qinshan Units 4 and 5) and Romania (Cernavoda Units 1 and 2) which in turn evolved from power reactor designs that go back to the Nuclear Power Demonstrator unit in 1962. Note that there are no CANDU 6 units operating in Ontario. India's indigenously well-designed and well-operated nuclear plants are based on CANDU PHWR technology.

The AP1000 was developed from the Westinghouse reactors now operating in the U.S. These in turn were developed from submarine reactors that Westinghouse built for the U.S. navy, starting with the USS Nautilus, launched in 1954. The U.S. EPR is based on the four Framatome (subsequently AREVA) N4 reactors, a completely French design, that was the latest reactor series to be put into service in France between 1996 and 2000, and on the three Siemens Konvoi series units in Germany. The earlier French reactors that started up in the late 1970s and after were based on a Westinghouse design supplied under the "atoms for peace" initiative of President Eisenhower.

The ESBWR is based on the General Electric ABWR (Advanced Boiling Water Reactor), four of which were built in Japan between 1996 and 2006 and two are being built in Taiwan. In turn the ABWR is based on the older BWR many of which are operating in Japan and the U.S.

Expected Capacity Factors

Capacity factor is an indication of plant performance and is the ratio of actual energy produced over a period of time to the amount produced if the plant were running at its maximum continuous rating over the same time period. The ACR-1000 is expected to operate with an annual capacity factor of 95 percent and the LWRs at up to 93 percent. The ACR-1000 does not have to shut down for refuelling although it will be necessary to shut down every three years, for three weeks, to do routine maintenance that cannot be done when the unit is operating.

The ACR-1000 and the LWRs are designed for a life of 60 years but the ACR-1000 will require a shutdown of less than a year, after 30 years service, to replace the tubes that pass through the calandria because of dimensional and material property changes due to radiation. This will also provide an opportunity to replace obsolescent equipment and do other refurbishment to meet contemporary standards. Such refurbishment is taking place on the CANDU 6 reactor in New Brunswick that started up in 1983 and had a lifetime capacity factor of 82.1 percent up to the end of 2007 and will also be done soon on the reactors in Korea (Wolsong Unit 1) and Argentina that started up in 1983 and 1984 respectively and had lifetime capacity factors of 85.7 and 84.9 percent respectively at end of 2007. LWRs need to shutdown for refuelling and maintenance so, all in all, lifetime capacity factors of the new reactors after 60 years could be expected to be similar at around 93 percent.

Actual Capacity Factors of The Reference Plants

Up to end of 2007 the average lifetime capacity factor for the 11 operating CANDU 6 reactors was 88.8 percent with an annual capacity factor also of 88.8 percent in 2007 down from 90.8 percent for 10 reactors in 2006. The four CANDU 6 units in South Korea had an average lifetime capacity factor of 93 percent up to end of 2007. India has operated its 15 PHWRs at close to 90 percent capacity factor but a shortage of natural uranium fuel has affected current performance.

The global fleet of PWRs and BWRs had a lifetime capacity factor of 81 percent. In the U.S. the "lifetime" capacity factor since year 2000 was 87 percent for all 103 operating reactors, not just the 52 Westinghouse PWR and 35 GE BWR reactors. Previous to year 2000 average capacity factors in the U.S. were low, in 1990 it was 66 percent and in 1980 it was 56.3 percent but today annual capacity factors are around 90 percent, for example 91.8 percent for 2007. In France the 58 PWR reactors, including the four of the N4 type on which the U.S. EPR is based, had an annual utilization factor of 80.2 percent in 2007, down from 83.6 percent in 2006. The N4 type has been around 75 percent and the Konvoi type at over 90 percent. The capacity factor of the French units is low, at around 77 percent, due to load following.

The four ABWRs (reference plant for the ESBWR) in Japan had a lifetime capacity factor of 64.2 percent up to end of 2006 with an annual capacity factor of 57.2 for that year. The 32 BWRS and 23 PWRs in Japan had an annual capacity factor of 63.9 percent and 79.2 percent respectively in 2006.

In countries that have both CANDU 6 reactors and PWRs, like South Korea and China, the CANDU 6 has out-performed the American and French reactors in Korea and the French reactors in China. Capacity factor depends on the way the plant is managed as well as on its inherent design.

Considerations

The AP1000 has design certification in the U.S. and the ESBWR and the U.S. EPR are in the design certification process. ACR-1000 is presently not in the design certification process. Design certification in the U.S. does not mean automatic, or even easier, licensing in Canada. The ACR-1000 has a planned in-service date of 2016. China has ordered four AP1000 reactors, while one EPR is under construction in Finland and another in France. The four French N4 design reactors on which the U.S. EPR is based suffered major delays in construction and AREVA's EPR in Finland is at least two years behind schedule and 25 percent over budget since start of construction in 2005. Of course lessons learned there could be applied to Ontario.

The latest CANDU 6 reactors in Korea and Romania were built on time and on budget. The two in China were ahead of schedule and below budget so, based on this, the ACR-1000 is expected to have a 42-month construction schedule for plants following the first. The CANDU 6 project in China holds the record for the shortest construction time for a nuclear plant in China. Romania is planning for two new CANDU 6s in addition to the two that are operating and Argentina is ready for new build. India is building more CANDU type reactors as part of its three stage plan to utilize its thorium deposits.

Future nuclear build will depend on a reliable supply chain. While both the ACR-1000 and the LWRs use enriched uranium the enrichment levels are much lower for the ACR-1000. The LWRs need large reactor pressure vessels. With the resurgence in demand for nuclear power plants worldwide a lot will depend on the limited availability of uranium enrichment facilities and on the very few suppliers of nuclear grade heavy forgings for fabricating the reactor pressure vessels and other large pressure retaining components. Ontario would have to take its place in the global queue for these services and components. The lead-time for delivery of LWR reactor pressure vessels is over 4 years. Some generation companies in the U.S. have ordered long lead items even before committing to plant build. The ACR-1000 can have much more local content, including the reactor itself, than other types of reactors which means more jobs in Canada.

Periods of low demand on the Ontario grid combined with generation from intermittent self-scheduling wind turbines will require a degree of load following from the nuclear units. France has demonstrated load following from its PWR fleet for many years even to the extent of shutting down units, and early CANDU reactors in Ontario and offshore have also shown their load following capabilities.

Accidents

Both CANDU and PWRs have suffered accidents. The small loss-of-coolant event at Three Mile Island PWR in 1979 escalated to a partial meltdown of the core and a permanent reactor shutdown. CANDUs have had several small loss-of-coolant events but with no fuel damage.

Safety

All plants are "safe" and all are said to be Generation 3+. However, the LWR vendors are having problems meeting the requirements of Regulatory Document RD-337, Design of New Nuclear Plants, that was issued for comment by the Canadian Nuclear Safety Commission (CNSC) last October. According to Linda Keen, ex President of the CNSC, this was a technology neutral document. The LWR vendors have raised many major technical objections, for example, the requirement to have two independent reactor shutdown systems like the ACR-1000. The safety of the ACR-1000 in beyond-design-basis accidents is enhanced by the cool heavy water moderator that surrounds the fuel channels and by the cool shielding water that surrounds the calandria in the reactor vault that act as emergency passive heat sinks. The U.S. EPR relies more on engineered safety systems than the AP1000, the ACR-1000 or the ESBWR.

Cost

New reactors will be based on standard designs to reduce construction times, and total costs, by extensive modularization and advanced construction techniques. Follow-on units will be cheaper and quicker to build than the first-of-a-kind unit. Reliable cost figures are hard to find. The overnight costs, which exclude interest over the construction period, could be, according to Nucleonics Week for 2006 July 6, \$1500 to \$1800/kWe for the AP1000, \$1800 to \$2000/kWe for the U.S. EPR and \$1600/kWe for the ESBWR. These numbers are probably for first-of-a-kind units and will vary widely depending on the source. AECL gives \$1000/kWe for the ACR-1000. The real construction cost will depend on construction time and interest rate.

Total generating cost (levelized unit energy cost) for the AP1000 is said to be less than 3.5 cents/kWh and 3 cents/kWh for the ACR-1000. This would be based on estimates of operations and maintenance cost, fuel cost, waste management and decommissioning costs, capacity factor, design life, capital cost and discount rate over the construction period. The Electric Power Research Institute (EPRI) estimates a general levelized cost of between 4.6 and 7 cents/kWh for new nuclear and the Organization for Economic Co-operation and Development (OECD) has come up with 3.2 to 5.3 cents/kWh. In 2007 the average production cost (includes operations and maintenance cost and fuel cost but excludes capital and interest cost) of nuclear in the U.S. was 1.68 cents/kWh from its 103 operating second generation PWRs and BWRs. Darlington production cost is 1.3 cents/kWh. For the consumer the total (levelized) generating cost is the most important consideration.

Hopefully this provides some background and clarifies some of the differences and some of the things that have to be considered in the selection of Ontario's new reactors.

Opinion Piece

Ed. Note: *The following is the opinion of the writer and does not represent the views of the editor or pulisher nor of the Canadian Nuclear Society.*

What would Warrant Selection Of CANDU?

by Bill Schneider

Foreword *- The views contained herein are my own words written on my own time – they do not represent those of any company or society with which I may be associated. They are intentionally provocative - because we are in a very tense situation for which stern action is required – and keeping things diplomatic and "smooth" will not achieve that. The New-Build Ontario competition puts the horizon for effective action very close indeed. In that situation, we, as an industry, may rise to the occasion – or who knows (?) - (?) think that's a joke (?).*

This is not intended to detract from the excellent work and limitless dedication of the many people of high achievement throughout the Canadian nuclear industry – it only seeks to draw attention to the challenge of the moment in an unambiguous way.

NRU"challenge" – the best thing to happen to CANDU - ever

The isotopes scandal and its fall-out is truly a case to which applies the saying –

"the more intractable the situation - the greater the opportunity for an excellent outcome"

The value of the NRU experience is that it has exposed the long-standing ineffectiveness of the organizational structures and management practices of the various key organizations involved. The Federal Government in power is to be commended for a remarkably strong response as "owner" - for digging into the confusion, identifying the weaknesses within the industry generally, challenging its mind-set and its endless self-justifications, and in initiating deep structural changes.

And how fortunate we are that the Regulator did not "do the right thing" and again (as it did endless times over decades past) provide a temporary easement to allow operation to resume under yet another of those many "deficiency lists" – in which case none of the current industry "self-examination" would ever have happened.

One has to have a great deal of admiration for the current and long-standing position of the Ontario Government which is basically – "…when we see an option which we could realistically (and responsibly) buy, we will consider buying it …" To that end, a new-build vendor selection process has now been set out in a transparent, competitive, two-phase process whereby the four lead vendors will each get to put up their best shot.

What Would a New-Build Customer's Requirements Be?

- A design which is fixed
- A procurement/construction plan capable of providing all of the program management, engineering, systems and equipment, construction, commissioning, etc on a competent, timely and cost-effective basis
- Contractors and partners committed and ready to execute of all of the above.
- A strong, project management-based organization structure
- An acceptable and competent price and delivery commitment.

Why not just go for it?

Many feel that (and I quote):

> *"… they [Provincial Government] should just approve the CANDU new-build projects and get on with it…"*

Appealing as it may seem, that is a Very Bad Idea – just think of that in terms of risk management and opposite the calamity-prone "Fast-Track" practices of the 60s thru 90s (such as pressure tube cracking, problematic and unnecessary pre-heaters, harmonic induced fuel damage, etc.).

Essential Re-organization

There are three essential features of any re-organization which are fundamentally important if the industry is to meet its challenges going forward:

1. **Chalk River Labs (CRL) and Sheridan Park Power Projects Group (SP) Must Be Operated As Totally Separate Entities.** This is necessary to make CRL accountable for its programs and its expenditures; and to isolate other parts of the organization from the "lab organization" culture which pervades all parts of the company.
2. **A New/External/Competent Project Management Organization Must Be Inserted Above/In Command of All Project Execution Work at SP.** This is necessary in view of the legacy of "lab organization" culture which pervades this organization. "Improvement" of the existing organization to make it operate like a true "Project-Competent" organization requires a significant culture change that is just not possible in time to match the competition. Instead, culture change could be achieved by either; a) insertion of an independent Project Management organization above and in control of all at SP; b) partial sale to "partners" who assume all control relating to project management and project delivery commitments or; c) out-right sale of SP in which case the new owner will impose their own management culture.
3. **Pre-licensing Analysis & Assessment Staff Work Must Be Assigned To Capable, Self-Managing Contractors (Consulting Engineering Firms) Working Under CNSC Staff.** This is necessary simply because there is no hope of getting competent licensing work out of the existing complement of Staff in any acceptable time-frame – there just aren't enough of them. Pre-licensing requires (for each design being considered) – establishment of Licensing Requirements; receipt (after their preparation) of the Application; a huge amount of analysis and assessment by Staff; and ultimately the issuance of the Construction and Operating Licence – all before the first sod is turned. The standard for Pre-licensing elsewhere is two years – without the above it will be the better part of a decade. Or – the Regulator may be forced (at the point where construction is to start) to once again "rush" an application for which compliance, to any acceptable standard, has not yet been demonstrated.

News of CNS Members and Colleagues / Nouvelles des membres de la SNC et collègues

Some Recent Retirements of CNS Members / Quelques retraites récentes de membres de la SNC

- Juris Grava, from Bruce Power, 2008 February / de Bruce Power, février 2008
- Judy Tamm, from AMEC Environmental, 2007 October / d'AMEC Environmental, octobre 2007

Best wishes for an enjoyable retirement! /
Meilleurs vœux de retraite agréable !

Best Paper Award in Reactor Physics at ANS Winter Meeting 2007 November

The paper by Eleodor Nichita (U. of Ontario Institute of Technology) and Benjamin Rouben (Consultant), entitled "Combining In-Core-Detector Readings with Diffusion in Eigenvalue Flux Calculations for CANDU Reactors", was selected to receive the Best Paper Award from the Reactor Physics Division (RPD) of the American Nuclear Society at the recent 2007 Winter ANS Meeting in Washington, D.C.

Send us news / Envoyez-nous des nouvelles!

Please send newsworthy items about CNS members, to be considered for inclusion in the next Bulletin, to Ben Rouben, roubenb@alum.mit.edu. Thank you.

Veuillez envoyer des nouvelles des membres de la SNC, qui pourraient être considérées pour inclusion dans le prochain Bulletin, à Ben Rouben, roubenb@alum.mit.edu. Merci.

Implementation of The Environmental Management Plan for The Dismantling of Nuclear Powered Submarines at Zvezdochka Shipyard, Russia

Michael Washer[1], Michael Cull, Clay Crocker[2], Valery Ivanov, Anatoly Shepurev[3],
Badi-Uz-Zaman Khan, Michael Lee, and Mark Gerchikov[4]

Ed. Note: The following paper was presented at the 28th Annual Conference of the Canadian Nuclear Society.

Abstract

Department of Foreign Affairs and International Trade Canada is funding the dismantling of twelve nuclear powered submarines (NPS) from the Russian Federation's Northern Fleet as part of the Global Partnership Initiative against weapons and materials of mass destruction. In this paper, work performed by Nuclear Safety Solutions Ltd. and its collaborators in support of these activities is described.

First, an environmental impact assessment of towing and dismantling NPS in the Kola Peninsula, and the Barents and White Seas was performed. The assessed activities included: towing of NPS from Naval Bases in Murmansk Region to the Zvezdochka shipyard (Severodvinsk); defuelling of onboard reactors; dismantling of NPS at Zvezdochka; and waste management. The assessment helped identify mitigation measures that could prevent the occurrence of adverse effects. Next, the project team defined and implemented an environmental management plan (EMP) based on the shipyard's existing environmental policy and the mitigating measures identified during the environmental assessment. Specific targets were defined to track the progress of the EMP implementation, and are described in this paper. During the study period, three Victor Class NPS were dismantled at Zvezdochka. The major benefits realized include: removal of spent nuclear fuel assemblies; treatment/decontamination of liquid and solid radioactive waste; and the cultivation of collaboration between Russian and Western expertise.

1. Introduction

Of the 248 submarines built by the Soviet Union and later Russia, 196 have been laid up so far. As of January 1st 2004, of the 117 submarines that have been withdrawn from active service in North West Russia, 56 still had to be dismantled. Altogether, Russia built over 450 naval nuclear reactors, of which two thirds were located in North West and one third in the Far East of Russia [1].

The Project to Dismantle 12 Out-of-service Nuclear Submarines ("the dismantling project") is a component of Canada's contribution to the broader Global Partnership Initiative against the proliferation of weapons and materials of mass destruction. Canada has joined other international partners, including the United States, Norway, Japan and the United Kingdom in securing the spent nuclear fuel (SNF) and the broad international initiative to rid the world's oceans of retired nuclear submarines.

The Canadian Foreign Affairs Minister announced on August 4, 2004 the signing of a $24.4million contribution to assist Russia to dismantle its decommissioned nuclear submarines. Since the Minister's announcement, three Implementing Arrangements (IAs) were put into place within two years. This paper focuses on the work performed during the first IA.

The first IA was completed in September 2005. It covered the dismantlement of three nuclear powered submarines with two nuclear reactors per submarine as well as associated infrastruc-

Table 1: Submarines dismantled during IA#1

Hull/ Factory #	"K" Number	Class	Displacement	Reactors	In-Service	Out-Of-Service/ Reactor Shutdown
643	K-527	Victor III	4824 t	2 x 72 MWt VM-4 PWR (OK-300)	1981	1998
645	K-298	Victor III	4824 t	2 x 72 MWt VM-4 PWR (OK-300)	1982	1994
608	K-438	Victor I	3555 t	2 x 75 MWt VM-4 PWR (OK-300)	1971	1995

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Figure 1: Location of the Zvezdochka Shipyard

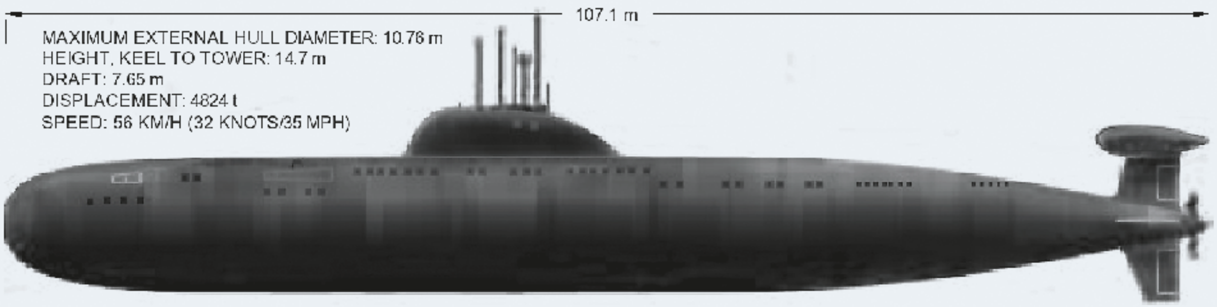

Figure 2: Victor Class Submarine

ture projects. Most importantly, IA#1 included the defuelling of six nuclear reactors and the securing of over a thousand fuel assemblies. Table 1 summarizes the details of the submarines dismantled under IA#1.

In addition, the project removes the threat of radioactive and chemical pollution from deteriorating submarines stored afloat. The dismantling project consists of all operations and activities that are required for the defuelling and recycling of 12 Russian Victor class nuclear submarines at the Federal State Unitary Enterprise (FSUE) Zvezdochka shipyard in Severodvinsk, Russia, with Canadian financial assistance. Figure 1 shows the location of the shipyard, while Figure 2 displays a typical Victor class submarine. Department of Foreign Affairs and International Trade Canada has assigned Project Monitoring duties to Teledyne Brown Engineering (TBE), which in turn contracted Nuclear Safety Solutions Ltd. (NSS) to provide nuclear, environmental and marine engineering monitoring services.

In late 2004, Nuclear Safety Solutions Ltd. (NSS), completed an environmental assessment (EA) of the dismantling project with support from Golder Associates Ltd. (Canada), TBE (USA), and NIPTB Onega (Russia). The EA was conducted under the Canadian Environmental Assessment Act (CEAA) and independently audited by the Canadian government due to the DFAIT funding of the work. A series of public meetings to seek local views on decommissioning programs funded by western donors was held in Severodvinsk and Moscow in 2004 and 2005 [1]. Public consultation was also performed in Canada. The EA recommendations were documented in the Environmental Management Plan (EMP) related to the dismantling project, which then became part of the contractual agreement for submarine dismantling. This paper highlights the major environmental milestones achieved, summarizes the progress against the EMP targets during IA#1, and describes the lessons learnt in the course of project implementation.

Table 2: Project Works and Activities

Works and Activities	Details
Preparation for Transit	Crew training, draining and depressurizing systems; inspection and modification of a submarine to ensure buoyancy during towing
Transportation of Submarine	Towing a submarine from its point of origin to Zvezdochka
Arrival and Acceptance	Mooring of a submarine at Zvezdochka
Preparations for Reactor Defuelling	Breaching of Reactor Vessel; Removal of flammable materials and some radioactive waste; metal work in preparation for bringing crane-borne defuelling tools to the reactor
Reactor Defuelling	Opening reactor lid, removing SNF from the reactor and transferring the fuel to specially-designed transport containers
Management of Spent Fuel	Loading special rail cars with filled transport containers to transport SNF by rail to the reprocessing facility at Mayak
Preparation for Submarine Dismantlement	Moving the defuelled submarine to either the docking basin (and its slipways) or to a floating dock; final clean-out of the submarine and preparation for major cutting and disassembly
Construction of Three-Compartment Unit	Cutting out the reactor compartment and one compartment to either side to create a seaworthy package containing the remaining radioactive components of the submarine
Dismantlement of Fore & Aft Compartments	Processing the submarine components remaining after formation of the three-compartment unit
Preparation of Reactor Compartment for Transportation	Outfitting the three-compartment unit for towing
Transportation of Reactor Compartment	Towing the three-compartment unit from Zvezdochka to Saida bay (near Murmansk) for long-term management
Management of Radioactive Wastes	Processing of radioactive wastes by existing facilities at Zvezdochka
Management of Non-Radioactive Wastes & Products	Processing of non-radioactive wastes and saleable products by existing facilities at Zvezdochka

2. Environmental Assessment For The Dismantling Project

2.1 Project Works And Activities

The dismantling project encompasses a chain of activities beginning with the preparation of a submarine for transport to Zvezdochka and ending with the salvage of uncontaminated materials, shipment of Spent Nuclear Fuel (SNF) for reprocessing at the Mayak Chemical Combine ("Mayak"), and receipt of a reactor compartment at Saida Bay for long-term, secure management (provided by funding from the German government). For the purpose of the EA and the EMP, the project works and activities listed in Table 2 were considered. Table 2 also outlines the dismantling process.

In addition, two accident categories were also assessed in the EA:

- **Conventional Accidents**, which included representative accidents with a reasonable probability of occurrence which do not result in a release of radioactivity (sinking, fire, spill of hazardous liquid etc.); and
- **Nuclear Accidents**, which included representative accidents (with a reasonable probability of occurrence) which do result in a release of radioactivity.

2.2 Scope of the Environmental Assessment

The spatial boundaries of the EA study encompass the city of Severodvinsk, Kola Peninsula and adjacent areas of the Barents Sea and White Sea (see Figure 1). The existing environment is described in detail for the local study area, shown on Figure 3:

2.3 Major Findings of the Environmental Assessment

Under normal conditions, a total of 65 interactions between the project works and activities and the environment resulting in possible measurable change were identified for detailed assessment. These included radiation doses to workers and releases to the atmospheric environment, as well as a number of effects from the identified representative malfunctions and accidents. The likely effects associated with each of these 65 measurable changes were considered and mitigation measures to eliminate, reduce or control any adverse effects were identified. The detailed assessment identified no residual adverse effects in view of mitigation measures. Fifteen (15) positive effects were identified, including three key benefits:

1. Transfer of highly-enriched SNF from a floating submarine to Russian fuel cycle facilities ashore, which ensures appropriate safeguards.
2. Removal of environmental risks associated with open-ended long-term storage of nuclear powered vessels afloat.

Figure 3: Local Study Area

3. Provision of employment at Zvezdochka shipyard in Severodvinsk and in the locations in Murmansk region where the submarine will be prepared for towing.

Detailed assessments of nuclear and conventional accidents were also carried out for the sinking of a submarine, fire, and a large spill of hazardous liquids. Changes in the environment were determined to be local and temporary. Detailed analysis showed that, given mitigation measures, representative accidents of each type were unlikely to lead to residual adverse effects.

In order to ensure that the mitigation measures are implemented, Department of Foreign Affairs and International Trade commissioned the Environmental Management Plan, which is constantly updated and ensures that the progress is monitored on a regular basis.

3. Environmental Management Plan For The Dismantling Project

3.1 Objectives

The objectives of the EMP are to assist FSUE Zvezdochka to:

1. **Minimize pollution**, including radioactive & non-radioactive discharges to air, land & water;
2. **Minimize waste generation**, including maximizing recycling & reuse;
3. **Enhance occupational safety**, including minimization of radioactive & conventional accidents;
4. **Enhance off-site public safety**;
5. **Manage waste safely**, including treatment/storage/disposal of radioactive & chemical wastes; and,
6. **Monitoring and Transparency.**

Section 4.1 summarizes the key activities that demonstrate the achievement of these objectives.

3.2 Specific Targets of the EMP

In order to meet these six major goals, the EMP specified several targets against which progress was measured. These included both radiological and non-radiological targets. This paper only addresses radiological targets, which are described in detail below.

- *To identify and eradicate the source of tritium leak at Zvezdochka.*

  Under normal operations, there are to be no radioactive discharges to groundwater. However, monitoring revealed the continuous presence of tritium in the groundwater.

  Although these levels are below Russian regulatory limits, they indicate either a continuous tritium leak or historic contamination within the Zvezdochka site. The source of tritium in groundwater is likely due to leakage from one of the industrial discharge pipelines from the liquid waste treatment facility. This source of leakage is consistent with the lack of other radionuclides in the measurements as only tritium is present in discharges in significant quantities. However, it is also possible that one of the historic radioactive waste storage sites is the source of the leak. In this case, other more radiotoxic nuclides would be present in the groundwater; the lack of other radionuclides in the monitoring samples could be the result of different migration rates of radionuclides from the source (tritium has the highest migration velocity because it is not absorbed). Therefore, it is necessary to first identify and then eradicate the source of the tritium leak.

- *To confirm the commitment to expeditious recovery of a sunken submarine if monitoring data warrants.*

  This target was set because of the potential of release of hazardous substances into the sea from a sunken submarine.

- *To develop capability for determining concentrations of pure-beta emitters (^{14}C, ^{63}Ni, ^{35}S, etc.) in liquid waste.*

  At present, the radiometric laboratory of the shipyard's Nuclear and Radiation Safety department produces results without a qualified measurement methodology for the specific activity of ^{14}C and ^{63}Ni. Not resolving the issue may result in the suspension of the discharge of the already-treated water from the liquid waste treatment facility to sea, as without clear identification of ^{14}C concentrations, the entire stock of the treated water may be classified as liquid radioactive waste according to Russian regulations.

- *To develop and approve a refurbishment project for the solid radioactive waste storage facility.*

  The project will require the retrieval, conditioning and packaging of all wastes currently stored, followed by the decommissioning of the waste store itself. The retrieval will likely be remote due to dose rates in the vicinity of the wastes stored within the building.

- *To ensure that there are plans for long-term management of the solid radioactive waste.*

  Although all radioactive waste storage facilities are designed for short-term buffer storage, there are no current plans to direct these wastes to national long-term storage and disposal facilities in the foreseeable future. Although such facilities exist in the region, they are currently used exclusively for the disposal of institutional (non-nuclear cycle) wastes.

- *To review procedures for monitoring radioactive waste inventories.* Improvement in the waste management practices could be achieved by collating all the hazardous chemical and radioactive waste inventory data.
- *To collate accurate worker-dose data and to reduce collective worker dose to 3 man-Sv, and to introduce the ALARA principle (As Low As Reasonably Achievable).*

  The available data suggest that there may be some scope to reduce overall exposure of the work force by introduction of ALARA principle and dose targets for each operation. It may be necessary to review equipment needs to ensure that high dose-rate operations involving spent fuel management can be undertaken remotely or with fewer personnel involved in the immediate vicinity of SNF containers. The number of workers involved in radiologically hazardous activities appears to be unjustifiably high. Measures need to be taken to eliminate any incentives to workers for receiving higher doses.
- *To review air quality, discharge effluent and stormwater data to optimize monitoring efforts and target any necessary corrective actions.*

  This measure is needed for monitoring the long-term effects of FSUE Zvezdochka operation and appropriately focusing any corrective actions.

4. Implementing Arrangement #1 And Progress Made In Meeting EMP Targets

4.1 Major Environmental Milestones

In the course of IA#1, FSUE Zvezdochka achieved a number of major environmental milestones:

- Removal of spent nuclear fuel from reactors of laid-up submarines, placement into TK-18 or TUK-108 casks and transfer to Mayak (see Figure 4)
- Treatment of Liquid Radioactive Waste (LRW), including primary coolant, spent decontamination solutions, shielding tank water and mixed effluents through filtration, selective sorption, evaporation and reverse osmosis (see Figure 5)
- Decontamination or size reduction and packaging of Solid Radioactive Waste (SRW) (see Figure 6)

Large quantities of non-radioactive, hazardous waste have been safely managed in this project, including thousands of mercury lamps, and several tonnes of acids, alkaline electrolyte, freons and hydraulic liquids. Furthermore, rubber and metallic scrap from dismantled submarines have been processed and sold for reuse.

4.2 Progress in meeting EMP targets through IA#1 activities

Table 3 provides details of progress made towards the targets listed in Section 3.2.

A - Preparation for defuelling

B - Loading of transfer flask with SNF assembly into SNF cask

C - Cask transfer to interim onsite storage

D - Transfer of SNF to Mayak

Figure 4: Spent Nuclear Fuel Management

It is important to note that the two in-progress targets in Table 3 are ongoing tasks that can (strictly speaking) be marked as “completed” only at the end of the dismantling project.

Figure 5: Liquid Radioactive Waste Management (Reverse Osmosis Equipment)

Figure 6: Solid Radioactive Waste Management - Intermediate Level Waste containers (left) and Low Level Waste containers.

4.3 Environmental Sampling Results

FSUE Zvezdochka has an extensive environmental monitoring programme. Regular sampling takes place on- and off-site to determine concentrations of radioactive substances in air, groundwater, surface water, soil and sediments. Radioactive discharges to sea as well as environmental concentrations of radionuclides (such as ^{137}Cs, ^{60}Co, ^{90}Sr, and ^{3}H) have all been less than 1% of their respective annual regulatory limits. Likewise, discharges of Kr-85 to air have been well within annual limits (<30%).

4.4 Opportunities for Improvements

Several opportunities for improvement have been identified over the course of completing IA#1 and implementing the EMP. The key opportunities were as follows:

1. The marine sampling programme is currently limited to sampling and analysis of seawater and sediments. It is recommended that sampling of marine biota should also be conducted to address the concerns of local population.
2. Solid Radioactive Waste storage facilities are rapidly filling up. In the absence of a national radioactive waste storage/disposal facility, FSUE Zvezdochka may have to construct a new SRW storage facility and implement further measures to minimize SRW volume. In addition, the shipyard was provided with information on western decontamination technology such as Vacu-blasting. The use of such technology would result in significant reductions in the quantity of solid radioactive waste as well as secondary liquid radioactive waste.
3. A training course for key personnel of FSUE Zvezdochka was conducted to demonstrate western safety and waste management systems and equipment.
4. Portal monitors are being installed in order to ensure that no radioactive materials leave the site accidentally,. The overall system would include portal monitors for vehicles, for railway traffic and, eventually, pedestrian monitors.

5. Conclusions – Lessons Learned

Dismantling of twelve nuclear powered submarines from the Russian Federation's Northern Fleet is proceeding as part of the Global Partnership Initiative against weapons and materials of mass destruction. An Environmental Management Plan based on the shipyard's existing environmental policy and the mitigating measures identified during the environmental assessment was developed. The following approach has been instrumental in ensuring good environmental performance for the project:

1. **Selection of a local facility with a good infrastructure in place**. FSUE Zvezdochka is unique in the region in that it has the following facilities.
   - **A land-based defuelling facility**. Most defuelling facilities in this region are not land-based; that is, the submarine is defuelled by another floating vessel. This causes stability problems and results in higher quantities of liquid radioactive waste, involves interim storage of spent nuclear fuel in a floating storage vessel and requires a larger number of fuel movements to ensure that the fuel is eventually transferred ashore.
   - **Liquid and solid waste treatment facilities**. Availability of these facilities at the shipyard minimizes the period required to store untreated, unpackaged and unconditioned waste and removes the need to transport this waste to another site.
2. **Selection of a local facility whose management is committed to preserving environment.** FSUE Zvezdochka has a highly qualified environmental team who have been instrumental in ensuring consistent environmental performance. Their existing

Table 3: Status of EMP Targets

Target	Details
	Completed Targets
To identify and eradicate the source of tritium leak at Zvezdochka	FSUE Zvezdochka demonstrated that the source of the leak has been identified/ eradicated. A marked decrease in concentrations was observed after repairs to the wastewater pipe from the liquid waste treatment facility.
To confirm the commitment to expeditious recovery of sunken submarines if monitoring data warrants	Complete
To review procedures for monitoring radioactive waste inventories	A functional paper-based system for monitoring radioactive waste inventory exists. Further improvements can be achieved via an electronic waste-tracking database system (see also the "Opportunities for Improvements" section).
	In-Progress Targets
To collate accurate worker-dose data, reduce collective worker dose and minimize risk of potential public exposure	A comprehensive system for monitoring effective worker dose exists. There is evidence that effort to reduce worker doses, especially during defuelling, has been made. There are additional needs to: - develop an automated system for radiation monitoring in the Restricted Access Areas, Controlled Area, and the surrounding plant and populated areas - procure a portable radiological laboratory to facilitate on site measurements during normal operation and after an accident. - ensure regular surface contamination monitoring (swipe tests) in all areas where potential contamination may occur.
To review air quality data to optimize monitoring efforts and target any necessary corrective actions	An extensive air, sediment, ground-, and seawater monitoring system exists. Sampling has been witnessed on several occasions and the collected data is reviewed on a monthly basis. See Section 4.3 for details.
	Targets not yet met
To develop capability for determining concentrations of pure low-energy beta emitters in liquid waste	FSUE Zvezdochka has requested Canadian assistance to develop a procedure which can then be certified with the Institute of Mendeleeva in Russia.
To develop and approve a refurbishment project for the solid radioactive waste storage facility	FSUE Zvezdochka is developing a concept to remotely retrieve radioactive waste by an overhead crane, followed by conditioning/packaging retrieved waste and decontaminating this facility. FSUE Zvezdochka is looking for funding for this concept. ROSATOM (the Russian nuclear regulator) plays a key role in defining funding priorities.
To ensure that there are plans for long-term management of the solid radioactive waste	Provision of a central radioactive waste storage or disposal facility is ROSATOM's responsibility.

environmental policy statement seeks to constantly improve the ecological situation and to prevent environmental pollution, and to develop and introduce an environmental management system compliant with the ISO 14001 standards.

3. **Formation of a partnership**. Environmental and safety recommendations made by the Canadian monitoring team are always discussed with FSUE Zvezdochka. Joint decisions are then taken to determine the most efficient, logical, and environmentally sound path to meet the objectives of the recommendation. FSUE Zvezdochka benefits from the use of best practice, experiences, and technology from the west, while Canada fulfills its commitment to non-proliferation of weapons and materials of mass destruction.
4. **Encouragement for addressing environmental issues**. Canada continues to monitor the implementation of the EMP as the project progresses. Some of the infrastructure funding has been specifically allocated to address EMP targets.

Environmental and nuclear safety monitoring visits have taken place on a regular basis since March 2005. The overall environmental performance has been good and the management at FSUE Zvezdochka has demonstrated commitment to continuous environmental improvement by investing into state-of the art waste treatment and storage facilities.

6. References

[1] Gerchikov M, Dutton M et al. "Strategic Environmental Assessment Report For Strategic Master Plan of Northern Dimension Environmental Partnership (Nuclear Window) – Executive Summary." *EBRD Contract 14073REV, 2005*. http://www.nssl.ca/SEA/Executive%20Summary%20Issue%204.pdf.

Materials Challenges for The Supercritical Water-Cooled Reactor (SCWR)

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Abstract

This paper discusses the materials requirements of the Supercritical Water-cooled Reactor (SCWR) which arise from its severe expected operating conditions: (i) Outlet Temperature (to 650 C); (ii) Pressure of 25 MPa for the coolant containment, (iii) Thermochemical stress in the presence of supercritical water, and (iv) Radiative damage (up to 150 dpa for the fast spectrum variant). These operating conditions are reviewed; the phenomenology of materials in the supercritical water environment that create the materials challenges is discussed; knowledge gaps are identified, and efforts to understand material behaviour under the operating conditions expected in the SCWR are described.

1. Introduction

A number of critical drivers have combined over the last few years to generate renewed interest in nuclear energy, both within Canada and internationally, creating the momentum for what is now being called a Nuclear Renaissance. These drivers include Sustainable Energy production and use, both from strategic and environmental considerations, and for Climate Change Mitigation. Concomitantly, there is now greater motivation to replace conventional emissions-intensive industrial processes in a variety of applications, including steam generation (for example, in extraction of fossil fuels from tar sands); for hydrogen production (both for emerging transportation technologies and for refining of crude oil); as well as for desalination of both seawater and inland brackish water; among several others, by emissions-free energy technologies. Given the essential emissions-free nature of nuclear energy, these drivers have renewed the impetus to further innovate existing nuclear technology along traditional dimensions such as safety, reliability, efficiency, economics and sustainability, as well as to explore the special issues that arise in these new applications. In view of increased commercial use of nuclear technologies, there has also been stronger impetus to design reactors with constructability and modularity in mind, and to build greater proliferation resistance into fuel cycles.

These technological and strategic considerations have led to the initiation and establishment of a number of international nuclear technology cooperative development initiatives, such as the Generation IV International Forum (GIF), the International Nuclear Energy Research Initiative (I-NERI), the Euratom Project on Reactor for Process Heat and Electricity (RAPHAEL) and the IAEA-coordinated International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO), among others. Canada is participating in several of these initiatives, with AECL being the primary institutional participant. Within the set of six reactor concepts proposed for R&D under the Generation-IV International Forum (GIF), Canada has taken the lead on the Supercritical Water-cooled Reactor (SCWR), recognizing (i) Considerable prior work AECL has carried out on variants of the basic CANDU[1] design using light water or supercritical water as the coolant, (ii) The fundamental complementarity between the basic CANDU design and the SCWR concept, and (iii) The facilities and expertise available in Canada to advance the R&D on the concept.

Canada is also participating in R&D on the Very High Temperature Reactor (VHTR), which is a graphite-moderated, helium-cooled reactor with a once-through, thermal spectrum, uranium fuel cycle, with an outlet temperature of up to 1000 C, where the United States has assumed the lead. Although VHTR is significantly different from CANDU in concept, participation in VHTR is desirable, because of (i) Likely spin-offs from its significantly accelerated development timeline relative to the other reactor concepts; (ii) The fact that VHTR development includes demonstration of process heat applications (thermochemical hydrogen production and coal gasification); (iii) VHTR development also includes demonstration of High-temperature Electrolysis (HTE). Canada has a strong interest in each of these technologies. Variants of CANDU reactors, perhaps including ACR-1000 and CANDU-SCWR, could be employed in similar applications in the future. The VHTR is more widely known as the Next Generation Nuclear Plant (NGNP) in the US, and is intended to function as such.

The new and more demanding operating conditions foreseen in Generation-IV reactor concepts arise from (i) **Fuel cycle innovations** (for example, fast spectrum neutron fluxes could result in radiation dosages up to 150 dpa on cladding materials, compared to about 15 dpa for thermal spectrum); (ii) The need for **higher outlet temperatures** for greater thermal efficiency (from about 300 C in PHWRs to about 625 C in SCWRs and 1000 C in VHTRs); (iii) **Novel coolant possibilities**, such as supercritical water, liquid sodium or molten salts, which interact more stressfully with materials comprising both the reactor core and the balance of plant than conventional light or heavy water coolants; and (iv) The **longer expected lifetime** of the reactors, at 60 years, compared to licensed lifetimes of 20-40 years for Gen-II or III reactors.

Generation-IV reactor materials will therefore be subject to higher levels of hydrostatic, thermochemical, and radiolytic stresses over a longer period than materials in currently operating reactors. Materials Issues thus form a cross-cutting R&D theme across all Generation-IV reactor concepts, and the Generation IV International Forum (GIF) has drawn up an Integrated Materials R&D Plan to address them. Many of these Materials Issues are also shared by projects whose primary goal is not reactor evolution

1 CANDU – (Canada Deuterium Uranium) is a registered trademark of Atomic Energy of Canada Limited.

per se but fuel cycle innovation or nuclear hydrogen production and, interestingly, nuclear fusion reactor development, including the International Thermonuclear Experimental Reactor (ITER).

Although materials issues are thus a cross-cutting theme, they possess a particular salience within the *SCWR* context. No *nuclear* reactor has yet been built using supercritical water as the coolant, while for the other Generation-IV concepts, even the VHTR, demonstration or experimental reactors of very closely related concepts have already been built, and coolant-material interactions are less uncertain. Significant questions exist for the SCWR, however, about how cladding materials, for example, will react to the combined radiological and thermochemical stresses in the supercritical water environment. Although many *fossil-fuel-fired* power plants using supercritical water have been built[2], there is no precedent for the type of radiological-thermochemical stress that materials in the SCWR reactor core will face, especially in a fast-spectrum fuel cycle. Though materials eventually to be used for the SCWR are expected to evolve from those currently being used in nuclear reactors generally, the issues specific to SCWR do warrant a detailed investigation. This effort is proceeding in Canada, both at AECL and at a number of universities, under the aegis of the I-NERI and the Generation-IV International Forum [1-6].

The goal of this paper is to review these Materials Challenges with particular reference to *SCWR*, and to provide an accessible discussion of issues for the typical interested professional who is not directly working in the field. This paper is organized as follows. In the next section, a brief introduction to the SCWR reactor concept is provided, followed by a discussion of the operating conditions that create the Materials Challenges. In Section 3, the phenomenology of supercritical water is reviewed, together with what is known about materials behaviour in SCWR operating conditions. In Section 4, a discussion of the Materials Challenges is provided, including a brief discussion of the work in progress that addresses these Challenges. Section 5 is the Conclusion.

2. The Supercritical Water-cooled Reactor (SCWR)

Expressed simply, the SCWR is a nuclear reactor cooled with (light) water in its supercritical state. As is well known, when heated under sufficient pressure, water ceases to boil. The distinction between liquid and gaseous phases vanishes at pressures greater than 22.1 MPa and a temperature of 374 C. This is known as the critical point. Above this temperature and pressure, water is said to be supercritical.

During the 1950s and 1960s, before the market dominance of PHWRs and LWRs, the SCWR concept had been proposed both in the nuclear and in the fossil-fuel-fired contexts, but interest subsequently dropped off in nuclear SCWRs. However, SCW boilers in fossil-fuel-fired power plants continued to be developed, and have now achieved very high market penetration. Even in the fossil-fuel-fired context, a number of materials issues did arise, and were significant enough to cool the initial enthusiasm for the concept. However, they were subsequently overcome, so the knowledge base generated during this process is of great relevance to the balance-of-plant design for SCWRs. Interest in *nuclear* SCWRs was eventually revived in the 1990s, through work in Canada, Japan, the US and Russia.

Much of the interest in the SCWR concept arises from the considerable expected increase in thermal efficiency (a nearly 33% increase over conventional PHWR or LWR) from the use of supercritical water as the coolant. This results from: (i) The higher range of operating temperatures that is possible; (ii) The high specific heat of supercritical water (which enables greater heat transfer per unit volume, thus permitting a lower mass flow rate compared to pressurized water as coolant); (iii) The fact that supercritical water does not change phase in the loop. These factors considerably simplify the balance-of-plant, reducing the size of pumps, piping and associated equipment, and improving the economics of the concept.

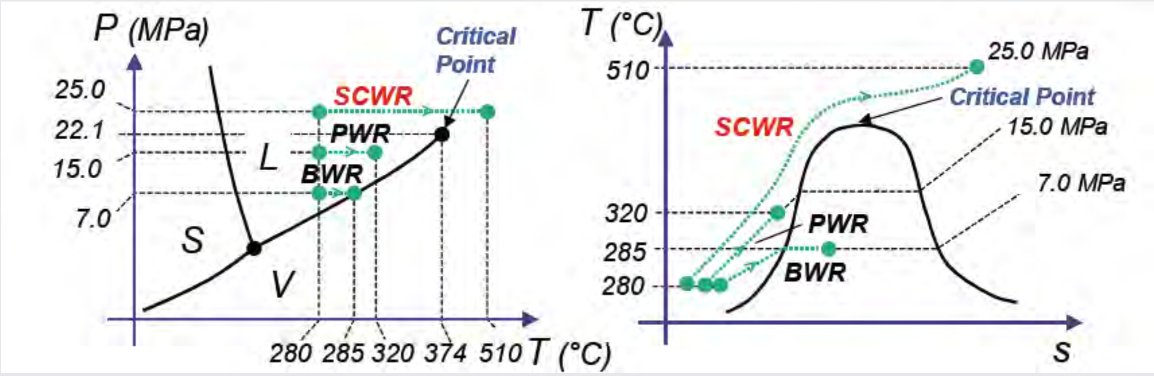

Figure 1: *Left:* Phase diagram of water, showing the critical point and the relative operating regimes of the Supercritical Water Reactor (SCWR), the Pressurized Water Reactor (PWR), and the Boiling Water Reactor (BWR). The reference temperature shown is that of the US SCWR variant, while the CANDU-SCWR outlet temperature is higher, at 650 C. *Right:* Temperature-Entropy diagram of water, showing the greater heat transfer possible above the supercritical point. From [7].

2 There are also other proposed industrial uses for supercritical water such as remediation of polychloro-biphenyls (PCBs) contamination, utilizing its superior oxidation properties; and supercritical-water-based chemical (non-electrolytic) hydrogen production through methanol reforming. These also generate useful data from the point of view of SCWR design and analysis.

Indeed, the superior expected economics of the SCWR is one of its major selling points. Use of a single-phase coolant also obviates the boiling crisis, a serious issue with PWRs, permitting temperatures to be safely raised and avoiding discontinuous heat-transfer regimes within the core, improving safety performance. Indeed, these considerations motivated the use of supercritical water as the coolant in fossil fuel fired power plants in the first place. It becomes natural, therefore, to investigate the possibility of a CANDU reactor design with a supercritical water coolant.

The synergy of the supercritical water coolant idea with the basic CANDU design is considerable. First, the physical separation of moderator (in the calandria) from coolant (in the pressure tube) reduces the coolant impact on neutron flux. Normally, this can occur from coolant and moderator both being present in high concentrations within the core. Secondly, with horizontal pressure tubes in CANDUs, the effect of density gradients within the coolant (which can be significant in supercritical water flow) as it moves through the reactor core, can be checked through bi-directional interlacing of adjacent channels, thereby balancing the density gradients by using flows in opposite directions and achieving a more axially uniform flux field [6]. This cannot be done in a vertical reactor pressure vessel (RPV) common to LWRs. In addition, the basic CANDU design can also smoothly transition to a slightly enriched uranium (SEU) fuel cycle with light water moderation, a flexibility that is a significant advantage within the SCWR design envelope. Another advantage is the relative ease of achieving a CANDU pressure tube capable of bearing a pressure of 23+ MPa that would be necessary versus achieving the same pressure in a larger Reactor Pressure Vessel (RPV) in PWRs [6].

The CANDU-SCWR concept also has the additional virtue of being potentially scalable to a fast spectrum fuel cycle. Independently of the SCWR concept, AECL has carried out a number of studies with thorium based fast-spectrum fuel cycles [9-10]. Combining this fuel cycle innovation with the SCW coolant can lead to both higher thermal efficiency *and* a more sustainable fuel cycle, and is therefore of considerable interest as a concept for the future. The outlet temperature envisaged for CANDU-SCWR (650 C) is

CANDU-SCWR Reference Design Parameters

- Direct Cycle
- Supercritical Water Coolant
- Outlet Temperature 650 C
- Thermal Cycle Efficiency 45%+
- Operating Pressure 25 MPa

Figure 2: CANDU-SCWR Reference Design Parameters. (From [8]).

somewhat higher than those proposed for the US SCLWR reference design (500-550 C). The higher temperatures *may* enable some thermochemical hydrogen production, but an electrolytic hydrogen production scheme is certainly possible using the electric power produced by the reactor. However, the economics of such a system must be carefully investigated. If a secondary steam generator is set up, to provide steam for various applications, in particular, oil sands recovery, then the overall economics can improve. A CANDU-SCWR system together with an electrolytic hydrogen production process and a steam generation process has many synergies to commend itself, and can improve both the environmental footprint and the economics within the context of oil sands recovery.

Today, state-of-the-art SCW fossil-fuel plants can sustain temperatures as high as 610 C and pressures as high as 25 MPa [11]. The balance-of-plant element of the CANDU-SCWR reference design is therefore pitched at the absolute cusp of current technological possibility. As a result of the substantial continuity in the design scope of the CANDU-SCWR reactor core, however, with current generation CANDU, a considerable body of existing knowledge regarding CANDU safety issues will continue to be valid for CANDU-SCWR. Furthermore, balance of plant safety and performance is well understood from the experience with fossil-fuel SCW plants. Given all these attributes in its favour, the CANDU-SCWR concept is expected to be the mainstay of the evolutionary path of the CANDU reactor, with a development trajectory projected as far as the year 2080 [6].

A slightly different SCWR concept based on the pressure-vessel design has also been specified: (i) With a light water-moderated thermal spectrum fuel cycle (SCLWR) (ii) A fast spectrum variant, without a moderator altogether. In addition to challenges for the cladding material similar to those with CANDU-SCWR, there are significant materials challenges for the SCLWR in the materials used to build the reactor pressure vessel (RPV) as well. The general SCWR concept has also been specified within a pebble-bed context, where the fuel consists of SiCcoated UO2 'pebbles', with a light water moderator. This concept has advantageous passive safety features, but some materials challenges also remain at the SCW interface. These SCWR variants are being developed in the US, Europe, and Asia.

3. Thermo-Physical Phenomenology of Supercritical Water

The thermo-physical phenomenology of supercritical water is briefly reviewed in this section, because it is pertinent to a discussion of the materials challenges in the SCWR context. The density of supercritical water is a strong function of temperature and pressure, and can easily vary by a factor of five or more in the operating temperature range of the SCWR (Figure 3).

The difference in properties between supercritical water and normal water, however, is most dramatic in the specific heat, and particularly so at the critical point itself (Figure 4). Another relevant property difference arises from the insolubility of inorganics in supercritical water, which raises the purity requirements for the intake (Figure 5).

When water becomes supercritical within the thermohydraulic loop, any inorganic impurities dissolved in it would be deposited on reactor materials. When such impurities are deposited within the reactor core, they could have harmful consequences for the thermal conductivity and structural stability of the cladding, as well as serious implications for neutronics and for reactor stability. Outside the core also, they would contribute to an increase in corrosive stress. Therefore the intake water in SCWRs should be as pure as possible; this is similar to the corresponding requirement

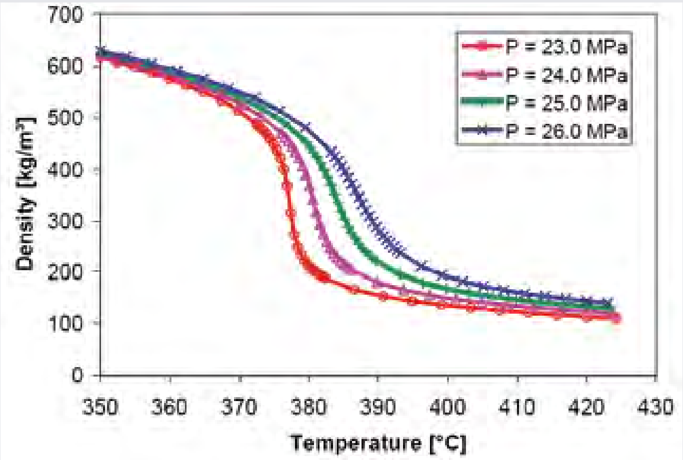

Figure 3: Density changes in supercritical water as a function of pressure and temperature. From [11]

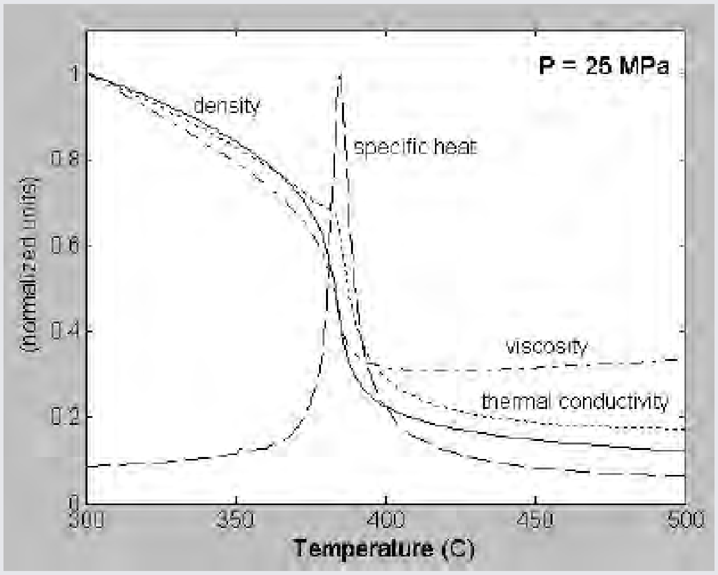

Figure 4: Thermal variation of physical properties of water, showing clearly the specific heat peak at the critical point. Density, viscosity and thermal conductivity are seen to decline significantly with temperature. A major consequence of the higher specific heat of supercritical water is that a far more efficient heat transfer can take place through the coolant, reducing the amount of mass flow required in the loop.

in Boiling Water Reactors (BWRs).

4. Materials challenges

The feasibility of the SCWR concept will be decided based on whether materials can be found that can withstand the combined thermal, hydrostatic, thermochemical and radiative stresses arising from the operating conditions over the lifetime of the reactor. This is a particular issue for in-core reactor materials, and less so for balance-of-plant materials, which can use materials previously tested in fossil-fired SCW plants. A brief review of the stainless steels and alloys that are currently used in nuclear plant structures

	Normal Light Water	Supercritical Light Water
Dielectric Constant	78	< 5
Solubility of Organics	Very Low	Fully Miscible
Solubility of Gases	Very Low	Fully Miscible
Solubility of Inorganics	Very High	Not Soluble

Figure 5: A comparison of some relevant properties of normal light water and supercritical light water.

is first presented, along with some basic water chemistry. The discussion will then cover effects of high temperature, pressure, and radiation; candidate materials for SCWR will then be outlined. Finally, a brief description of the ongoing experiments and plans is provided. A more comprehensive discussion is available in [11].

4.1 Ferritic, Austenitic and Martensitic Steels

Steels are classified by their structure into *ferritic*, *austenitic* and *martensitic* steels. *Ferritic* steels are highly corrosion resistant, but not as durable as austenitic steels. *Austenitic* steels are the most widely used stainless steels; over 70% of stainless production is austenitic. They are characterized by a face-centred cubic microstructure. Austenite is stable only above 723°C in carbon steel, but alloying elements such as nickel and manganese, stabilize it at low temperatures. *Martensitic* steels are named for the distinctive needle-like structure (martensite), which comes into being as austenitic steel transforms during quenching. Currently, martensitic and ferritic steels and their nickel, manganese, carbon and chromium alloys are widely used in reactor materials.

Reactor materials are stressed by four main factors (and their collective impact): (i) High temperatures. (ii) High Pressures (iii) Thermochemical environment (iv) Irradiation flux.

4.1 High Temperatures and Pressures

The high operating temperature and pressure in SCWRs can induce a heavy stress on the structures. There is usually a maximum pressure that structures can handle at a given temperature without failure, defined by the bulk modulus of the structural material. But interestingly, this pressure threshold rises with temperature, and most structures in the power plant are designed to handle the operating pressure only at higher temperatures. Even though structures can be designed in this way to withstand stresses without breaking, long-term phenomena like *creep* pose significant challenges. Creep is the slow plastic deformation of materials under constant stress. Creep occurs when the large number of preexisting lattice dislocations in a given material start moving slowly in response to the external load. At the microstructural level, these dislocations reach a metastable equilibrium, resulting in the hardening of the material. At low temperatures, the material would freeze in this condition, but at higher temperatures, the vibration

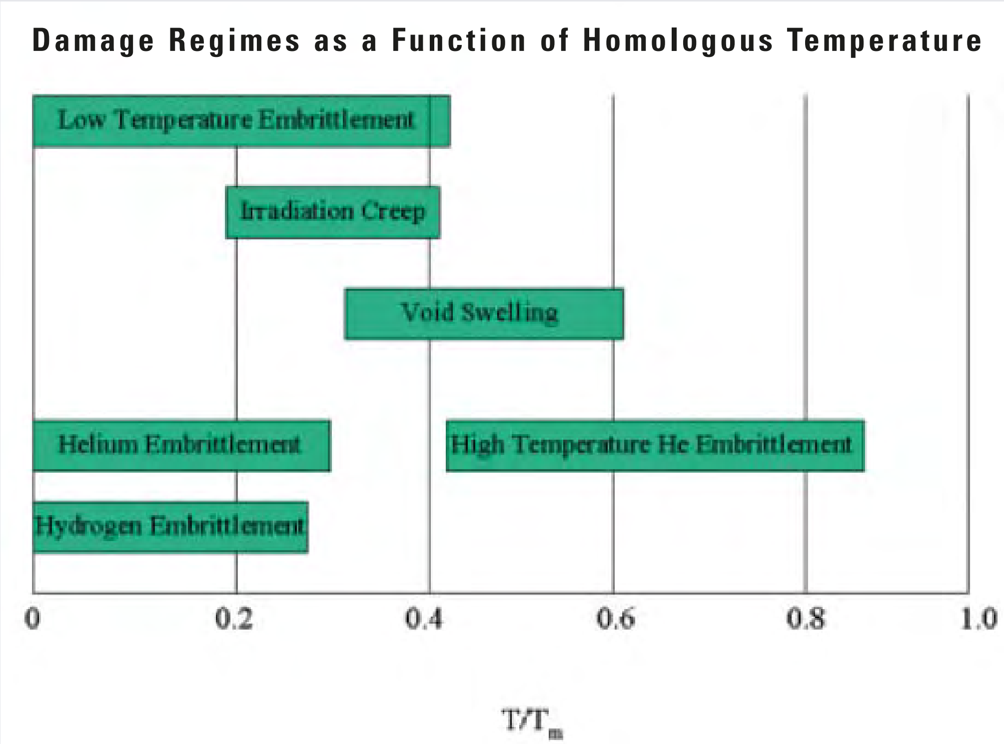

Figure 6: A diagram sketching out the different damage regimes applicable to alloys used in reactor materials, as a function of the homologous temperature. (Homologous temperature is the temperature in fractions of melting temperature.) From [12].

of atoms creates restoring forces, which tend to repair the dislocations. Cyclic variations in the pressure can cause additional stresses to structures. These stresses appear at lower values than the critical steady pressure for a given system, and must be properly considered during the plant operation. The limiting factor for the operating lifetime of the reactor is creep that accumulates over the years. Also, the combined effects of chemical corrosion and stress on the materials may cause *stress corrosion cracking* (SCC).

4.2 Irradiation

When a material is irradiated, all of its physical properties can change. Physical dimensions as well as the electrical, mechanical, magnetic, thermo-physical and other properties can each change. During irradiation, the kinetic energy dismantles the atomic lattice first, and lattice-restoring forces then reconstruct it, atom-by-atom. In high-dose irradiation, each atom may be displaced from its lattice site many times, the standard measure of which is the displacements per atom (dpa). The specific conditions at the time of irradiation, such as temperatures, and local material composition, in addition to dose and dose rate, ultimately determine the property changes that will result. The irradiation-induced changes of greatest concern are (i) Swelling, (ii) Irradiation creep, and (iii) Embrittlement.

4.2.1 Swelling

Swelling is the isotropic volume expansion of an irradiated material, occurring by the net absorption of interstitials at dislocations, with a corresponding net number of vacancies accumulating at cavities. At high doses, tens to hundreds of dpa, swelling may reach several tens of percent or more of original volume. In graphite, which has a very anisotropic crystal structure, swelling can itself be anisotropic and is highly dependent upon the graphitic microstructure and the macroscopic direction of a component with respect to the crystal texture.

4.2.2 Irradiation Creep

Irradiation creep is the slow change in the shape of a material in response to an applied radiative stress, over and above the ordinary thermal creep described above. Irradiation creep can occur even at low temperatures, where thermal creep is largely absent.

4.2.3 Embrittlement

Embrittlement takes place through two processes. In the first, the hardening results from *microstructural movement of the dislocations*, which reduces ductility. The second type of process is *grain boundary weakening*, caused by preferential diffusion of transmutation products, such as helium, or tramp elements, such as phosphorus, to the grain boundary. Either process has the effect of reducing the elasticity of the material and lowers the pressure threshold.

4.3 Water Chemistry

The single most important variable that is likely to impact the practical operation of the SCWR is the chemistry of supercritical water in the presence of radiation. While the effects of water chemistry will be most critical in the SCWR reactor core, there could also be 'spillover' effects on the balance of plant systems. Control of the chemical composition of the coolant water is therefore very important. The observed mechanisms for chemical environment-sensitive cracking in water-cooled reactors are (i) Intergranular stress corrosion cracking (IGSCC), (ii) Irradiation-assisted stress corrosion cracking (IASCC) and (iii) Corrosion fatigue. These phenomena are affected by:

- Metallurgical structure, phase morphology, and depletion of metallic species such as Chromium from zones adjacent to grain boundaries;
- Irradiation effects on grain boundary impurity segregation; and
- The presence of oxidizers and reducers dissolved in the water.

IASCC in austenitic stainless steels is more significant above a *radiative fluence threshold* of about 1 displacement per atom (dpa). Further, in nickel-based super alloys IASCC is sensitive to the presence of impurities such as phosphorous, silicon, boron, or sulphur.

The question of how structural materials previously used in PWRs or LWRs will perform in SCWRs is uncertain. The details will depend on precisely how the SCW water chemistry is different. Specifying the operating temperatures in the SCWR does not by itself automatically determine the water chemistry, the major reason for uncertainty. The concentrations of the transient and stable species which are formed through (i) radiolysis of the water in the presence of radiative flux, and (ii) thermal decomposition of the water due to the higher operating temperature, may well be significantly different from the situation in LWRs and PWRs. The situation will be exacerbated in a fast spectrum fuel cycle environment, where a higher radiative flux will likely radiolyse more water, changing the equilibrium concentrations of the transient and stable species. The chemical potentials of oxygen and hydrogen peroxide that are formed in this process also affect the corrosion potential of the water. It can be expected that these potentials will be significantly different in supercritical water as compared to subcritical water. The concentration of these species also determines whether magnetite (Fe_3O_4) or hematite (Fe_2O_3) will form during oxidation, and it will also affect the actual morphology of the oxide films, which are important to corrosion control in steels.

Similarly, the chemical potential of the hydrogen is likely to be different in supercritical water, just as the chemical potential of the oxygen would be, and the water chemistry of hydrogen could be effective in reducing the oxygen content. The reaction rate of the OH radical with hydrogen has been known to decrease above 300 C, increasing the relative probability of thermolysis of the water molecule and the equilibrium concentrations of the ionic species. In the reactor core, water will thus be radiolysed, but since this process is kinetically determined, it might require much more hydrogen to suppress the oxygen and peroxide generation. If too much hydrogen is required for oxygen suppression, metal hydrides could form. The trade-off between (i) hydride formation and (ii) oxygen and peroxide generation will mainly determine how much of the LWR and fossil plant water chemistry control experience is applicable to the SCWR. The pH of the water is important in setting the corrosion potential and rate, and to some extent, also the mode of corrosion. A range of pH has been previously successfully employed in PHWRs and LWRs, and the applicability of this approach to SCWRs will need to be explored. The control of pH, while theoretically possible, may be difficult in practice, however, especially in the 300 to 650 C temperature range [13].

While the SCWR itself is unprecedented, there does exist a body of experience regarding performance of reactor materials in water environments developed in the operation of LWRs and supercritical fossil-fired power plants that may be relevant – either directly, or after appropriate interpolation. Control of the water chemistry will be critical to the continued operation of the SCWRs just as it has been for LWRs.

Boiling water reactors (BWRs) also normally operate with an oxygen overpressure. The water environment in BWRs tends to be slightly acidic because of the CO_2 in air, which leads to formation of carbonic acid. The consequence is another rather aggressive environment, which, though qualitatively different from that expected in SCWRs, can still be expected to cause excessive corrosion of the reactor materials. In BWRs, the rough rule of thumb is that the propensity for SCC will increase with increasing oxygen content, so hydrogen is added to the intake water to recombine with the thermolysis-generated oxygen, and thus limit the corrosion to a value below the threshold for onset of SCC. However, significant hydrogen overpressure is needed to induce recombination of oxygen with hydrogen. More recently, thin layers of noble metals (e.g., platinum and rhodium) have been deposited on the surface of BWR structural materials to suppress the corrosion potential, and then a relatively low hydrogen injection level is sufficient.

The PWR on the other hand, is less susceptible to air infiltration, operating an indirect cycle. However, even PWRs have an oxygen overpressure due to diffusion of radiolytic hydrogen out of the coolant system. Hydrogen is therefore also injected in the primary coolant of PWRs, but at lower rates than in BWRs. A minimum temperature of about 300 C and a pH of 6.9 is required to avoid heavy crud deposits on the fuel rods. Boron is also added to the PWR coolant as boric acid to act as a neutron absorber for reactivity control. To counter the effect of the boric acid on the pH, lithium hydroxide is dissolved into the PWR primary water. In once-through fossil-fired units of the type considered for SCWRs, pre-treating the intake water usually controls the quality of the coolant water. Some combination of these and similar strategies, which must be studied in detail for SCWRs, will be needed to address the water chemistry – radiative stress environment for supercritical water and the challenge it represents to material structural integrity [13].

4.4 Materials Selections and R&D for SCWR

Given that the three factors that will most affect the properties and choice of the structural materials from which the SCWR components will be fabricated are (i) effects of irradiation, (ii) high-temperature exposure, and (iii) interactions with both the sub- and supercritical water environment; an extensive testing and evaluation program is required to assess the effects that these factors have on the properties of potential SCWR materials. The overall goal is to enable a preliminary selection of the most promising materials to be made, and to then qualify those selected for the service conditions required. This effort is already underway, and among several ongoing projects in Canada, [4] provides an overview of the Materials Evaluation for SCWRs under I-NERI at AECL.

That project is designed to investigate issues such as mechanical properties, dimensional and radiation stability, corrosion resistance, and stress corrosion cracking (SCC) in the candidate materials. While details are available [4], only some general considerations will be discussed here.

The greatest materials challenge presented by the SCWR will be in the qualification of materials that experience *both* high temperature and radiation exposure and which must simultaneously survive the hostile supercritical water environment. The fuel cladding is perhaps the material component that will receive the highest levels of this type of combined stress. Also, since modified pressure tube designs with an insulator are being considered specifically for SCWRs, their materials will have similar requirements [6]. While fuel cladding will be periodically replaced as reactors are refuelled, other structural components should have a much longer expected lifetime, so both types of components will have demanding requirements. Fast spectrum fuel cycles will offer even more stringent demands on the materials.

In structures where the temperatures will be significantly above 300 C, or radiation doses above several dpa are expected, as is true for the SCWR reactor core, the candidate structural materials are primarily Ferritic or Martensitic steels and low swelling variants of Austenitic stainless steels. The range of compositions within the Fe-Cr-Ni alloy system with acceptable mechanical behavior and dimensional stability that currently exist, or could be developed, are in four broad categories: a) austenitic stainless steels, b) F/M steels, c) high alloys (Fe <50 wt.%) and d) Nibased alloys. However, currently there is not a sufficient knowledge base for predicting the stress corrosion cracking (SCC) or irradiation-assisted stress corrosion cracking (IASCC) behavior under supercritical water conditions.

Some alloys have also demonstrated low swelling in doses of up to 50-100 dpa in both mixed spectrum and fast reactors in the temperature regime of 450-550 C. Ferritic-martensitic steels in the 9-12% Cr range are intrinsically more swelling resistant than austenitic steels. Low swelling has been demonstrated in these alloys at doses of 50-100 dpa in neutron irradiations. In recent years, a class of advanced ferritic steels has been the focus of strong interest for nuclear applications: the Oxide-Dispersed-Strengthened (ODS) steels. In the ODS steels, the cubic-centered structure provides the irradiation swelling resistance while the dispersed oxides (e.g., yttrium oxides) provide enhanced high-temperature strength. The high-temperature creep strength of these alloys is exceptional even at 650 C (the reference outlet temperature of the CANDU-SCWR [8]). Significant international activities are ongoing to develop and optimize this class of materials, and work in Canada is also investigating them [4].

However, the principal issues with all ODS alloys relative to their application in the SCWR remain (i) significant uncertainties regarding their interaction with the supercritical-water coolant, (ii) high cost of fabrication and (iii) weldability. Nevertheless, because of their potential, ODS alloys are being investigated carefully in the SCWR materials R&D program.

5. Conclusion

The Supercritical Water-cooled Reactor, SCWR, one of the most promising of Generation-IV Reactor concepts, with its (i) many synergies with the basic CANDU design; (ii) superior economics; (iii) higher thermodynamic efficiency; (iv) potential for advanced fuel cycles (SEU or thorium-based); and (v) diverse application possibilities in hydrogen production, coal gasification and electrolysis – has been adopted as the mainstay of the likely evolutionary trajectory of the CANDU reactor, known in this context as CANDU-SCWR [6].

Before the CANDU-SCWR design can be fully specified, finalized and operationalized, however, significant challenges must be addressed (*a*) in understanding material behaviour in the operating conditions that are foreseen, and then (*b*) in down-selecting and qualifying suitable materials for use in its reactor components. The effort to address these materials challenges is well underway in Canada [4]. Projects to support these efforts are being carried out (i) at AECL;

(ii) at universities; (iii) under university-AECL collaborations; and (iv) under international cooperative initiatives. This effort will remain active well into the next decade [8], as part of a proposed development timeline that could see an operational CANDU-SCWR during 2025-2060 [6].

This paper has provided a general discussion of some of the most important challenges facing materials to be used in constructing the Supercritical Water-cooled Reactor, including (i) basic thermo-physical properties and (ii) radiological phenomenology of (*a*) candidate reactor materials and (*b*) supercritical water. General considerations and R&D issues regarding some candidate materials including ODS steels, have also been outlined. It is the author's hope that the paper will serve as an accessible overview of the field for the interested professional not directly working in it.

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A Human Error-Based Risk Assessment Model

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Abstract

A major component of risk assessment is that of human error. Identifying and calculating overall risk requires that the analyst consider how operators, maintainers, and support staff contribute to the causes of hazardous conditions that may lead to serious, disastrous, or catastrophic consequences. A computerized model has been developed by Rhodes & Associates Inc. to be run for marine, aviation, and rail operational scenarios. The model automatically calculates predicted risk values. The author will present the model's components and describe how the model may be applied to nuclear operations.

1. Introduction

Risk and error management strategies have been shown to improve safety in high-risk process industries [1]. These strategies can expose those areas where improvement should be made, and can also be used to uncover underlying causes of unsafe conditions that were present during incidents. The former is proactive, while the latter is responsive. Many techniques exist that can be used to apply both proactive and responsive approaches to risk and error management. The main thread that ties all of the approaches is the focus on human error causation. That is, getting to the root of what in a system leads people to err. The most comprehensive and practical of all of the methods is referred to as the system approach to error reduction [1]. This approach is based on Reason's model of error causation and accounts for all internal and external influences (see Figure 1).

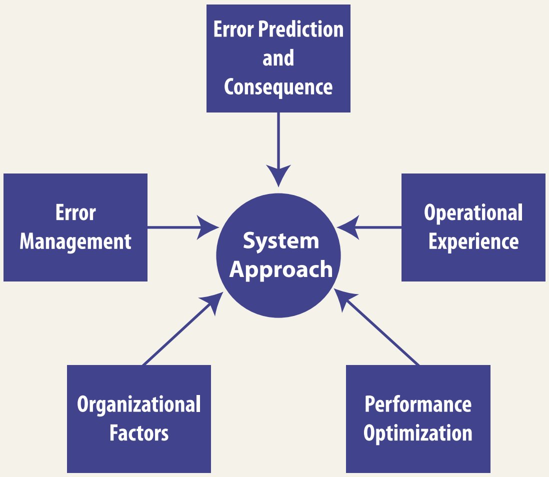

Figure 1 System Approach to Error Reduction

The system approach involves the collection and analysis of data from several sources:

- Organizational information on company safety culture, policies, the views of upper management, and mission statements
- Data from error reporting systems, error management experience, and audit reports
- Operating Experience (OPEX) and formal incident reports
- Interviews with operational staff and observations of day-to-day practices
- Design improvement and upgrade documentation (including recommended changes to equipment and procedures design)

The human error risk model proposed here is but one tool to be used to understand the impact of errors on system safety. The model can be used to obtain data on human error modes and types, and their associated risk to the operation, staff, and the public. Hence, it can fill the role of the upper most box in Figure 1, Error Prediction and Consequence.

2. Background

The model presented here was developed initially to examine the risk posed by fatigue on aircraft maintenance tasks. It was immediately realized that the mix of the tasks included both physical and cognitive tasks that were highly coupled. This required an examination of the impact of fatigue on these tasks, and a thorough analysis of the potential errors that could occur, as well as the impact of these errors on safety. An initial model was built and over the years during application to other modes of transportation (rail and marine), was refined. The model shows promise as a tool to quantify the human error contribution to the safety risk of systems, and can be used to measure the impact of error reduction and management systems.

Several approaches exist that provide practical methodologies for error reduction and management [1], [2], [3] [4]. These approaches are comprehensive and incorporate all of the elements described above for the system approach. They also handle cognitive as well as behavioural task data. This is important given that most of the activities in modern automated process systems are cognitive in nature. Some highly theoretical approaches also exist that are much more detailed and elegant, but these tend to be more difficult to apply in the field (see Hollnagel's book for one of the most comprehensive, theoretical treatments [5]). Hollnagel's description of the Cognitive Reliability and Error Analysis Method (CREAM) provides a very good understanding of the cognitive bases underlying the nature of human errors [5].

The methodology followed by the Center for the Chemical Process Safety (CCPS) entitled *Guidelines for Preventing Human Error in Process Safety* [1] appears to be the most practical to apply to nuclear power operations. In fact much of the methodology presented is based on earlier techniques used in the nuclear power industry, with considerable updating and additions to ensure adequate coverage (i.e. computer-based user interfaces and increased automation).

3. Methodology

The current work presented in this paper draws upon the methodologies mentioned above and combines the fundamental elements with an error analysis and reduction technique developed by Williams [6] referred to as the Human Error Analysis and Reduction Technique (HEART). The HEART technique is a simple approach to assign quantitative reliability information to specific tasks, modified to account for the effects of the prevailing error producing conditions for specific scenarios. HEART is used to quantify the error data in terms of frequency and to incorporate the effects of error producing conditions (called performance shaping factors [PFCs] in CCPS's approach). The error data is then incorporated into a risk table that allows calculations of risk values for each scenario. This approach has been used to integrate human error effects into the basic risk model described in CSA/CAN Q850-97 [7]. The approach consists of the following steps:

1. Collection of task, human error, EPC, hazard, consequence, and mitigation data
2. Compilation of data into a task database
3. HEART analysis
4. Event tree analysis for specified scenarios
5. Creation of scenario-based risk tables
6. Identification of associated mitigation strategies
7. Analysis of costs and benefits of mitigation strategies

Figure 2 illustrates the relationship between these steps.

3.1 Collection of Task-Related Data

The data collection involves interviews with each individual of a group that is representative of the employees affected. These interviews will examine the existing and potential hazards, the tasks involved, errors that may occur, estimates of their frequency, consequences that may occur, and mitigations that may be potentially useful. Focus groups involving a representative sample of the workers also can provide such information but may be biased by the influence of certain vocal individuals. However, focus groups involving representatives from the stakeholder groups can

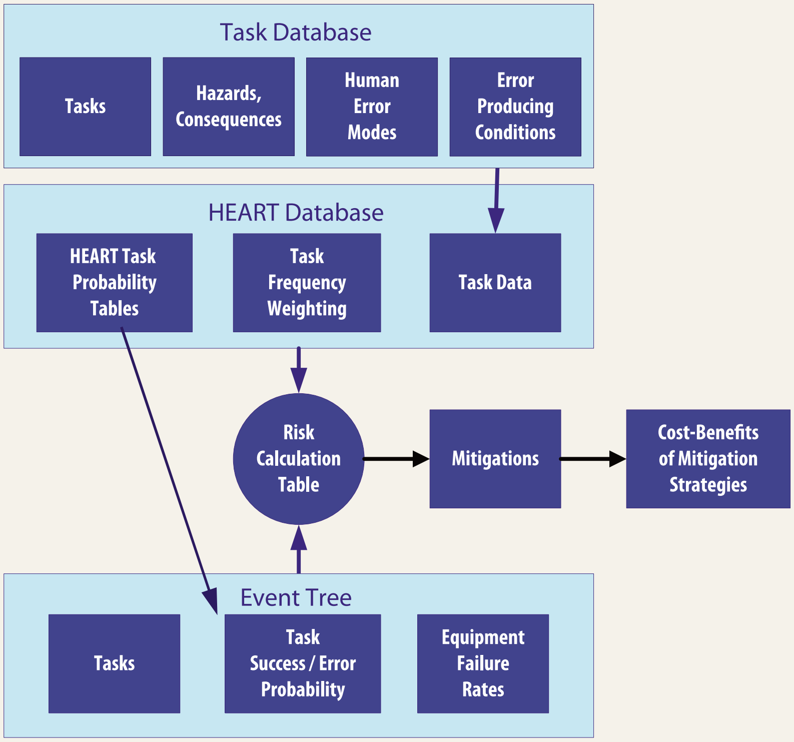

Figure 2 Steps Involved in Development of Human Error Risk Model

provide general information on hazards, consequences, and mitigations. Employees should be observed during typical work scenarios while they perform their duties. During these observations important task information, potential error modes, safe practices, and risky practices may become more apparent.

3.2 Compilation of Task Database

The database contains the following data components:

- Representative scenarios that include each task
- Task and critical-subtask descriptions
- Potential critical human error modes associated with each task
- Identified hazards associated with each task performed during the selected scenarios
- Potential consequence of the error modes for each task
- Nominal error frequency for each task
- Error producing conditions (EPCs) affecting each task and their weighting according to representative scenarios

Task	Nominal Task Error Frequency	Error Modes	EPCs Involved	EPC Multiplier	Weighting for EPC Multiplier	EPC Products Cond. A	EPC Products Cond. B
Brief Description	Derived from experience and tables	Description of all relevant error modes	List of all relevant EPCs	Multiplier for each relevant EPC	Weighting applied to each EPC multiplier	Task prob. X each weighted EPC less 1, multiplied together for first condition	Task prob. X each weighted EPC less 1, multiplied together for second condition

Figure 3 HEART Table Structure

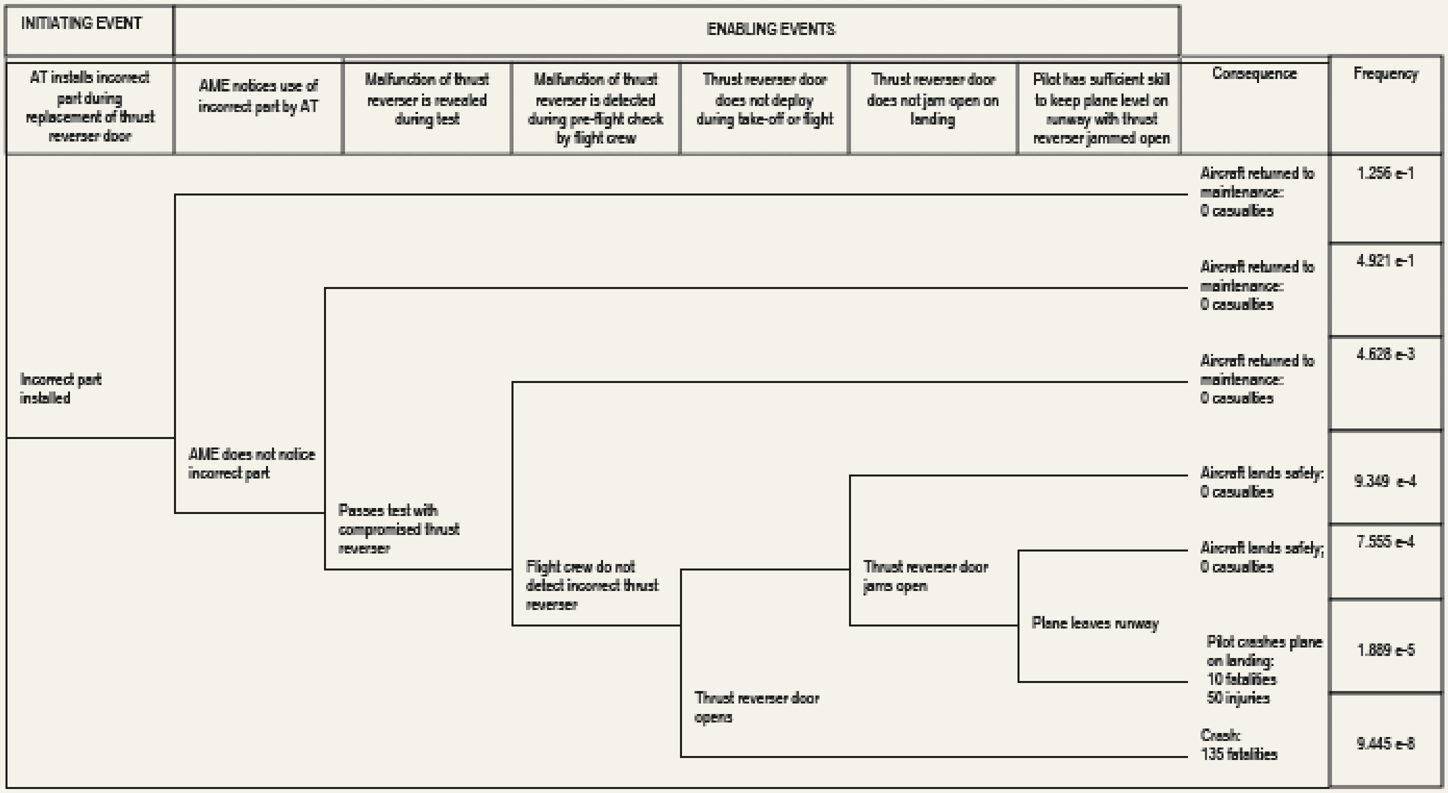

Figure 4 Example of an Event Tree

3.3 Human Error (HEART) Analysis

The task data is used to populate the HEART analysis table including the HEART calculations (application of EPC multipliers and EPC probability sums) and specific comparative calculations (e.g. fatigued condition versus rested condition; single operator operation versus two operator operation; present system versus improved system). Figure 3 illustrates the mechanics of the table.

The following equations describe the calculations necessary to arrive at the adjusted probability of unreliability for each task.

(EPC_i) = (EPCM – 1) x (EPCP) + 1 (1)

Where:

EPC_i is the contribution of a specific EPC to the overall level of unreliability

EPCM is the EPC impact multiplier

EPCP is the proportion of estimated effect of the EPC on error occurrence

The EPC multipliers are taken from Williams [6].

The proportion of estimated effect is determined by the expert judgement of the analyst using criteria that includes:

1. The proportion of time that the EPC would apply to a particular situation (scenario); and
2. The strength in which the EPC would influence the erroneous action.

The result in Equation 1 is an estimate for the contribution of particular EPC to the overall unreliability of a specific error mode.

The contributions of each EPC are multiplied together to arrive at the overall estimate of unreliability posed by a particular error mode, as shown by Equation 2:

Total EPC Effect = (Contribution of EPC_1) x (Contribution of EPC_2) x …(Contribution of EPC_n) (2)

The result in equation 2 gives the combined effect posed by the EPCs.

3.4 Event Tree Analysis

The risk table is based on the output from the event tree analysis which is done on a scenario by scenario basis. The event tree analysis uses the data produced by the task and HEART analyses, including tasks, error modes (initiating and enabling error events), calculated error and success frequencies, and final calculated frequencies of outcomes. Figure 4 shows an example from the aircraft maintenance task risk assessment.

3.5 Scenario-Based Risk Tables

The data resulting from the above analyses is placed in an Excel table that is structured to calculate the overall risk levels expected for each scenario, combined with consequence levels, resulting in overall risk outcomes for each scenario. The table automatically calculates these overall risk levels once it is populated by the data produced by the initial analyses.

3.6 Identification of Mitigation Strategies

Some mitigation strategies are identified during the earlier data collection phase (during interviews, focus groups) and according to the types of potential errors that may occur (skill-based,

Likelihood	Severity of Consequence				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost Certain	High Risk	High Risk	Extreme Risk	Extreme Risk	Extreme Risk
Likely	Moderate Risk	High Risk	High Risk	Extreme Risk	Extreme Risk
Moderate	Low Risk	Moderate Risk	High Risk	Extreme Risk	Extreme Risk
Unlikely	Low Risk	Low Risk	Moderate Risk	High Risk	Extreme Risk
Rare	Low Risk	Low Risk	Moderate Risk	High Risk	High Risk

Figure 5 Risk Table

rule-based, and knowledge-based). For skill-based errors, training may be required. Rule-based errors may be better resolved through improved procedures and practices. Other strategies are determined from the risk analysis and risk assessment research literature, and past risk assessments of similar problems. This multi-pronged analysis allows for optimum coverage and practicality. Each scenario containing specific mitigation strategies is compared for overall risk levels.

3.7 Costs and Benefits of Mitigations

The mitigation strategies are analysed for their costs and potential for lowering risk. Analysis of the scenarios that include each mitigation strategy are compared for:

- Results of risk comparisons for each scenario before and after introduction of each mitigation – (overall risk level = outcome consequence level X outcome frequency)
- Whether training, redesign of equipment, staffing, or policy changes are required
- Associated costs for each mitigation
- Risk reduction potential (risk before mitigation – risk after mitigation)

4. Risk Assessment

The information produced by the risk tables can be converted to standard risk terms (see Figure 5). Each scenario can be assigned an overall risk level and compared with those in the table to determine what scenarios need immediate mitigation regardless of costs, and what scenarios require a cost benefit analysis. For example those scenarios that may occur often (according to the frequency of relevant potential error modes or experience), or result in catastrophic outcomes, mitigations should be applied immediately. Of course, this also includes those that may occur often and result in catastrophic outcomes. For scenarios that are rare events and do not result in serious or catastrophic outcomes a cost-benefit analysis should be used to determine those mitigations to be applied.

6. Application to the Nuclear Power Industry

The approach described above can be effectively applied to the nuclear power industry and shows promise as a means to make risk-based decisions regarding staffing, processes and procedures, equipment and systems design, and company policies. Decisions based on these analyses will result in an optimum lower risk to personnel, the system, and the public. The method, combined with scenario-based error analysis and hardware/software reliability analysis, can be used to determine risk levels inherent in the existing systems (proactive approach). The method provides a means to integrate human actions and their associated error modes (and rates) into the probabilistic risk assessment.

Once the existing risk levels have been established, mitigations can be considered to improve the level of risk. A new risk level can be calculated for each mitigation under specific scenario conditions. This approach allows the analyst to run the model for all scenarios including selected mitigations as part of that scenario (e.g. new equipment design, improved training, or revised procedure etc.). All risk data for each scenario is combined to arrive at the overall system risk level. The new system risk levels for all scenarios combined can be compared to baseline levels established by the nuclear industry. Those mitigations that reduce the risk to just below accepted standard, and that are the lowest cost, would be considered to be the optimum approaches.

Also, a calculation can be made to determine the risk associated with various mitigation strategies considered as solutions to improve safety after the occurrence of a disastrous or catastrophic incident (reactive). Again the model allows the analyst to calculate the risk values for several mitigation strategies. The resulting risk levels can be compared to the baseline standard. Those strategies that are less costly can be considered to be the optimum choice.

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Ed Note. There is probably more controversy about nuclear activities in the town of Port Hope, Ontario, the home of Cameco's conversion plant and its subsidiary, Zircatec Precision Industries, than in any other community in Canada. Much of the concern comes from the history of what was the refinery of Eldorado Mining & Refining dating back to the 1930s. Jim Arsenault, a CNS member in the Ottawa area who has become very interested in the history of Canada's nuclear program provides a technical account of the early operation of the refinery.

Eldorado Port Hope Refinery – Uranium Production (1933-1951)

by J.E. Arsenault

Introduction

Since the discovery of pitchblende in 1930 by Gilbert LaBine at Great Bear Lake (GBL), N.W.T., uranium has played a central role in the growth of the Canadian mining sector and it in turn has propelled the country into it's present position as the world's top uranium producer. The rich ore mined there was used originally by Eldorado Gold Mines Limited to build a business based on the extraction of radium, which was selling at $70,000 a gram at the time, and silver which was present in the ore in commercial amounts. The mine site on GBL became known as Port Radium.

In 1933 Eldorado brought a refinery on-line at Port Hope, Ont., nearly 4000 miles away from the mine, and began to produce radium, silver and uranium products. Initially uranium played a minor role in the business and the products were sold into the ceramics industry to manufacture a variety of crockery with long-lasting colours. In addition, there were sales and loans of uranium products to research laboratories that were exploring nuclear energy for possible use in weapons and power generation, as the potential for this was clearly understood from 1939 onwards. These laboratories included the National Research Council (George Laurence), Columbia University (Enrico Fermi) and International Chemical Industries (J.P. Baxter).

With the beginning of World War II the radium business suffered from poor sales and by 1940 the mine was closed but the refinery continued operation, using accumulated stockpiles. By 1942 uranium had become a strategic material, the mine was reopened, and the refinery began to produce large quantities of uranium oxide destined for The Manhattan Project. As events unfolded Eldorado was unable to produce sufficient ore from GBL so that a large quantity of ore from the Belgian Congo was also processed at Port Hope. Ultimately, as a result of the efforts of this enterprise, World War II was finally ended by use of atomic weapons.

After World War II the refinery continued to produce uranium products for export and for use in the fledgling Canadian nuclear research program at Chalk River, Ont., which led ultimately to the CANada Deuterium Uranium (CANDU) family of nuclear power reactors so familiar today. Until 1951 uranium was produced using purely chemical methods, then new processes (including resin ion exchange and solvent extraction) came to dominate because of their relatively lower cost and high recovery. This article reviews the Port Hope refinery operation from 1933 to 1951, particularly during the peak uranium production years of 1943 and 1944.

Radium Recovery

Radium recovery techniques can be traced back to Marie and Pierre Curie, who in 1898 succeeded in isolating radium from pitchblende using acid to dissolve the always present uranium into solution, precipitation of the radium, followed by purification and multiple fractional distillations to concentrate the radium suffi-

Figure 1. Port Hope refinery circa 1933 (Library and Archives Canada)

Figure 2. Early photo of refinery's production area (Library and Archives Canada)

ciently. Uranium at the time was simply discarded. Until 1904 the Curies were associated with the Paris School of Industrial Physics and Chemistry, famous as an engineering institute. A graduate in chemical engineering from the School, Marcel Pochon, was, therefore, acquainted with the Curies and their radium research. Pochon subsequently acquired extensive research and industrial experience in Europe and was running a small radium refinery at a defunct pitchblende mine in Cornwall, U.K., when he was recruited by Eldorado in 1932 to set up and operate a radium refinery at Port Hope.

The Refinery

The refinery, shown in Figure 1, was located near the harbour front bounded by the old John and Marsh Streets, in buildings some of which were built as early as 1847 as part of a grain shipping terminal. Eldorado acquired the site, about two football fields in size, in a pure stock transaction with the owners of the Morrow Seed Company (operating in difficult depression times). Figure 2 shows an early production area with Marcel Pochon possibly in the photo (wearing hat), complete with vapor streaming from crocks, and puddles of liquid lying on the floor.

In 1942 and thereafter, the refinery was expanded considerably to cope with the demands of The Manhattan Project and a new three-storey refinery building was built. The whole complex was essentially given over to the production of uranium oxide. At the same time the refinery was converted from a batch process to a continuous process. In 1943 the company was renamed Eldorado Mining and Refining Limited and in 1945 became a crown corporation, Eldorado Mining and Refining Limited (1944), as part of the Canadian government's desire to oversee all matters nuclear.

All indications are that working conditions in the refinery were anything but adequate compared to contemporary standards. The refinery was dealing with tons of corrosive chemicals on a daily basis and about seven tons of chemicals were required to process one ton of concentrate in 1944. The capacity of the refinery at that time was 250 tons of concentrate per month and it resembled more of a chemical factory than a mineral processing plant. Ventilation was poor and safety protocols were not well developed but nevertheless were in tune with the times and there was a war on.

Input

Pitchblende from GBL had unique properties and radium extraction would have turned out to be problematic except that the Canadian government provided much assistance, because the Mines Branch was intimately familiar with the ore, having analyzed it on an ongoing basis from soon after the discovery. As refinery manager, Pochon had the benefit of flow sheets developed by the Mines Branch to combine with his extensive knowledge of radium extraction gained in Europe. At this point Eldorado was able to go ahead with a radium refinery with a small role assigned to uranium. The Mines Branch flow sheets show a uranium recovery of well over 99% based on small-scale testing.

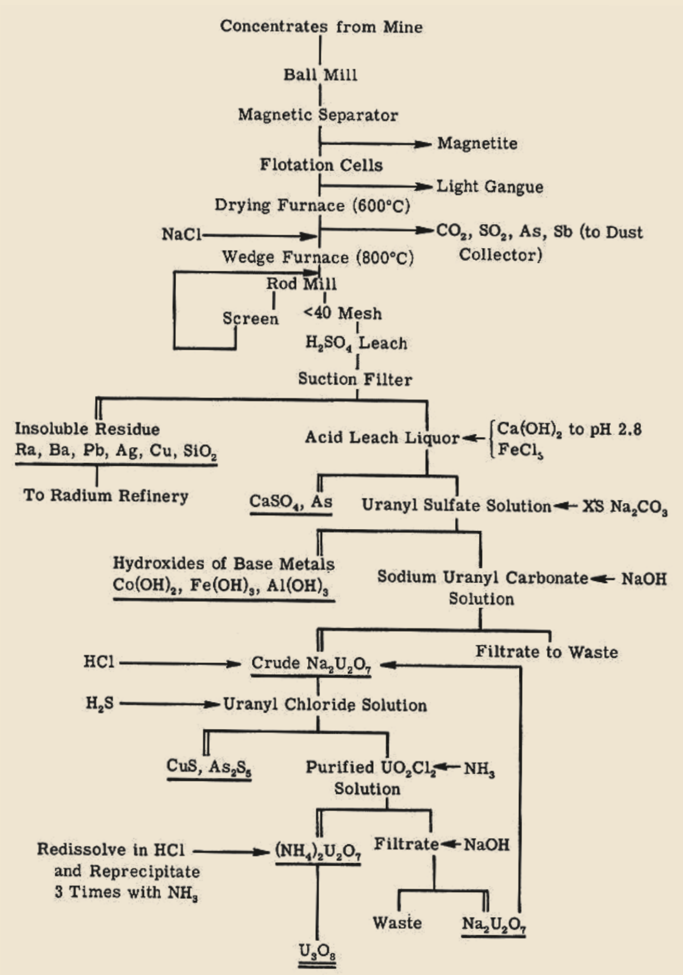

Figure 3. Flow sheet for production of U3O8 from Great Bear Lake pitchblende

Processing

As has been mentioned, the refinery processed pitchblende from GBL and the Belgian Congo. Whether they were processed separately or blended necessitated different processes. The following description of uranium processing during the peak production years of 1943 and 1944 is compiled from several sources: mainly Katz and Rabinowitch (1951), supplemented by Farmer (1945) and Merritt (1971). It includes basic chemical equations to allow the reader to 'follow the uranium' without the complications associated with the removal of the many impurities present. Text quoted verbatim from Katz and Rabinowitch is in *italics* and author inserts are indicated by < >. The flow sheet given in Figure 3 is from Katz and Rabinowitch.

The recovery process is complicated by the presence in the ore of considerable quantities of gold and silver. Carbonates and sulfides, which are also present, must be destroyed before the acid treatment; otherwise considerable frothing occurs. In addition, considerable amounts of arsenic and copper must be removed. The ore mined at Radium City <Port Radium> *on Great Bear Lake is concentrated in the ratio of 50/1 by mechanical separation and flotation. The mined rock contains about 1 per cent* U_3O_8. *The concentrate contains about 50%* <typically 25%> U_3O_8 *and from 1 to 7 per cent silver, depending on the section of the mine. This concentrate is shipped to the Port Hope (Ontario) refinery.*

The chemical problems associated with uranium recovery from African <Belgian Congo> *pitchblende are on the whole simpler than those encountered in its recovery from Canadian ores. Since gold and silver are absent, the roasting process with calcium chloride (or the alternative cyanide treatment) can be omitted. Some other minor modifications of the Canadian process are usually introduced in processing the African ore, particularly in the extraction step.*

a. Handling, Milling and Roasting

<Ore concentrate was delivered to the refinery in 100-lb sacks by rail car, unloaded, placed in storage and sampled for chemical analysis.> *The concentrate is first pulverized in a ball mill and sent through a magnetic separator to remove magnetite. A series of flotation cells removes the lighter components of the ore. The product from the flotation cells is dried in a furnace at 600°C, which decomposes the sulphides and carbonates and volatilizes part of the arsenic and antimony. Sodium chloride is then added, and the temperature is increased to 800°C; this converts silver to AgCl.*

b. Leaching

After cooling, the roasted material is leached with sulfuric acid to remove the uranium, manganese, copper, and iron. At the leaching stage it is customary to add barium chloride to provide the carrier for the radium present and ensure that it remains in the undissolved portion of the ore. The pH of the acid extract is adjusted to 2.8 by the addition of calcium hydroxide, and ferric chloride is added to remove arsenic as insoluble ferric arsenate. < Calcium chloride is commonly known as "slaked lime" or "hydrated lime" and is used in agricultural applications to neutralize acid soil. Because pitchblende consists of mixtures of UO_2 and UO_3 tending to UO_3 we can write a simple equation for the leaching process.>

$$UO_3 + H_2SO_4 > UO_2(SO_4) + H_2O$$

c. Iron Filtration

After filtration, a sufficient excess of sodium carbonate is added to solubilize the uranium and to precipitate ferric, aluminum, and manganese hydroxides, etc. <Sodium carbonate is commonly known as "soda ash" and so named because it was originally produced by the burning of plant material, until modern production techniques were developed.>

$$UO_2(SO_4) + 3Na_2CO_3 > Na_4UO_2(CO_3)_3 + Na_2SO_4$$

d. Crude Precipitation

After decantation, sodium hydroxide is added to the uranium tricarbonate liquor to precipitate $Na_2U_2O_7$. <Sodium hydroxide or "caustic soda is most familiar in the form of household drain products. $Na_2U_2O_7$, or sodium diurinate, is the familiar "yellowcake" in unpurified form.>

$$2(Na_4UO_2(CO_3)_3) + 6NaOH > Na_2U_2O_7 + 6Na_2CO_3 + 3H_2O$$

The sodium diurinate is purified by dissolving it in hydrochloric acid and saturating the solution with hydrogen sulfide, which precipitates the sulfides of copper and arsenic.

$$Na_2U_2O_7 + 6HCl > 2(UO_2Cl_2) + 2NaCl + 3H_2O$$

e. Refined Uranium

After the excess hydrogen sulfide is removed by boiling, ammonium hydroxide is added, and the uranium is recovered as $(NH_4)_2U_2O_7$. <Ammonium hydroxide is familiarly sold in dilute solution as household ammonia.>

$$2UO_2Cl_2 + 6NH_4OH > (NH_4)_2U_2O_7 + 2(NH_4)_2Cl_2 + 3H_2O$$

f. Oxide Burning, Pulverizing and Packing

This < $(NH_4)_2U_2O_7$ > *is converted to* U_3O_8 *by ignition at* 1000^0C <in clay crucibles>. *The oxide so produced has a* U_3O_8 *content of 97 to 99 per cent.*

$$9(NH_4)_2U_2O_7 > 14NH_3 + 6U_3O_8 + 15H_2O + 2N_2$$

<The burned oxide is crushed and pulverized, sampled, and packed in 100-lb packages for shipment.>

Table 1. Uranium (black oxide) production at Port Hope, by year

YEAR	QUANTITY (tons)	YEAR	QUANTITY (tons)
1930		1940	1.8
1931		1941	23.2
1932		1942	235.4
1933	0.9	1943	1355.0
1934	0.8	1944	594.6
1935	5.8	1945	387.7
1936	2.4	1946	147.6
1937	9.1	1947	200.0
1938	23.8	1948	206.0
1939	9.8	1949	217.0
		1950	235.0
		1951	225.0

Output

The production figures for uranium at the Eldorado Port Hope refinery for the years 1933 to 1951 has been compiled into Table 1, using data from various sources and is expressed in short tons (1 ton = 2000 lb) of U3O8, in the form of black oxide, the most stable uranium oxide. Figures for 1933 through 1946 are taken from Eldorado records (LAC: RG134, Vol. 108 and Vol. 164). These show that production potential for 1946 was 295.2 tons, but since the plant was shut for about half of the year due to strikes at suppliers chemical plants, a figure of 147.6 tons is derived. Figures for 1947 through 1950 are given by Bothwell (1984). For 1951, Bothwell indicates that production was between 200.0 and 250.0 tons, so an average figure of 225.0 tons is derived.

Production started in 1933 with just 25 employees and continued at a relatively low, if sporadic, level until 1941. Thereafter, uranium was recognized as a strategic material, The Manhattan Project began, and production at the refinery was ramped up rapidly to the peak year of 1943 when there were 287 employees. Essentially the same amount of concentrates was processed in 1944 but the grade was lower by about half. Production in 1945 was lower still and except for the plant shutdown in 1946 annual production out to 1951 was fairly flat. Of course the oxide that was produced for The Manhattan Project was refined into fissile material in the U.S., which used it with devastating effect in Japan, contributing to the cessation of World War II.

Aftermath

Pochon ran the refinery until 1945 when he resigned or was dismissed under a cloud, when Eldorado was put under investigation for criminal conspiracy to defraud. The criminal charges were dropped in Canada but there was an out-of-court settlement of $2M in the U.S. The very beautiful Muidar (radium spelt backwards) house at 108 Dorset Street remains, from which Pochon walked to work, and there is a Pochon Avenue in the town. The production of radium ceased in 1953 but uranium products have always been produced since the refinery opened.

The company was named Eldorado Nuclear Limited in 1968, Eldorado Resources Limited in 1982 and later still was merged with the Saskatchewan Mining and Development Corporation in 1988 to form Cameco. Today at the greatly expanded refinery site, which still has the remains of parts of the old refinery, Cameco produces ceramic-grade natural uranium dioxide for the manufacture of CANDU heavy-water reactor fuel and uranium hexafluoride for export and subsequent enrichment into fuel for light-water reactors. Cameco Corporation, now the largest uranium producer in the world, with headquarters in Saskatoon, Sask., produced 10,450 tons of U_3O_8 in 2006 and employs 420 at the Port Hope plant. Figure 4 is an aerial view of the Port Hope plant taken from the northeast in 2003, with the old refinery stack and power house near the centre (see photo).

Operations at the refinery have been controversial at times due to radioactive contamination, as a result of refinery operations. The community has often been split in its opinions on the refinery cost/benefit equation. The issue has never really left the town and since 1982 has been under the purview of the Low Level Radioactive Waste Management Office (LLRWMO), sponsored by the federal department of Natural Resources Canada and operated by Atomic Energy of Canada Limited (AECL). The stated goal is to clean up and isolate low-level radioactive waste in the surrounding town area, with storage in above-ground facilities designed to last at least 500 years.

Acknowledgments

For assistance in the preparation of this article thanks are due to my wife and traveling companion, Lyn, for patient editing and advice; Alexandra Lewis at Natural Resources Canada for locating obscure papers; Doug Prendergast at Cameco for photos and notes; NWT Archives for a report on the operation of the refinery; Canada Eldor Inc. for access to certain Eldorado files; Port Hope Archives for extracts from the Port Hope Evening Guide; Library and Archives Canada (LAC) for tracking down catalogued materials.

Figure 4. Cameco plant at Port Hope *(photo courtesy of Cameco Corporation)*

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CORRECTION

In a previous article in the Bulletin ("The Montreal Lectures: 2 August – 2 October, 1944", Vol. 28, No. 2, June 2007) it was implied that the lectures were delivered in 1944. New research shows that the lectures actually took place in 1945 (month and day are correct). Two references cited in the article indicated delivery in 1944 but a copy of the lectures recently obtained by the author from The National Archives at Kew, U.K., clearly show that they took place in 1945. It is surmised that the authors of the two references, published in 1965 and 1966, may not have had direct access to copies of the lectures–they were probably still classified at that time.

The old adage that the weakest ink is stronger than the strongest memory has been proven once again.

GENERAL news

Ontario Invites Bids for New Build

On March 7, 2008, Ontario Minister of Energy, Gerry Phillips, announced a two-phase Request for Proposal process to select a vendor for replacement nuclear power plants.

The Ministry of Energy, OPG and Bruce Power have already carried out a review of available nuclear technologies and have invited four vendors to participate in the first phase of the proposal process. The four vendors and identified designs are:

- Areva NP – US Evolutionary Pressurized Reactor
- Atomic Energy of Canada Limited – ACR 1000 Advanced CANDU Reactor
- GE Hitachi Nuclear Energy – Economic Simplified Boiling Water Reactor
- Westinghouse Electric Company – AP 1000 ™ nuclear power plant

The announcement noted that the same four vendors are currently competing for new nuclear build in the United Kingdom.

In phase one of the process, the prospective bidders will have to demonstrate a plan to deliver a construction licence application on schedule and in compliance with Canadian regulatory requirements. The winning bidder will also need to have the capacity and financial strength to deliver the project by 2018, with groundbreaking taking place in 2012.

A commercial team directed by Infrastructure Ontario will manage the procurement process. Team members will include Ontario Power Generation (OPG), Bruce Power, the Ministry of Energy and the Ministry of Finance. A two-member decision review board will review the competitive process. The process will be scrutinized by a "fairness monitor."

The announcement repeated the government's 20-year energy plan of 2006 that included:

- energy efficiency gains of 6,300 megawatts of electricity;
- double renewable capacity to 15,700 megawatts by 2025;
- eliminate coal-fired generation by the end of 2014;
- add additional gas-fired generation for use in peak periods;
- maintain nuclear energy capacity for baseload operation up to the current level of 14,000 megawatts.

The Minister had stated earlier that the province will select whichever company, foreign or local, that offers the best technology at the right price.

Bruce Power Alberta applies for site licence

On March 13, 2008, Bruce Power Alberta announced it had filed an application with the Canadian Nuclear Safety Commission to prepare a site for the potential construction of western Canada's first nuclear power plant. This followed its completion of its deal to buy the assets of Energy Alberta Corporation relating to nuclear power plant development.

Bruce Power Alberta is considering up to four reactors that could produce 4,000 megawatts of electricity. The company noted that the Alberta Electric System Operator estimates an additional 5,000 megawatts of supply will be required by 2017 and 11,500 megawatts by 2027 to meet the growing needs of Albertans.

The first unit could be ready as early as 2017, pending the successful completion of a full Environmental Assessment (EA) and consultations with the local communities. To begin the consultation process, Bruce Power Alberta will host a series of introductory Open Houses on Monday, April 14 from 6 to 8:30 p.m. in several Peace Country communities.

As part of the decision-making process, which could take up to three years to complete, additional Open Houses, workshops, consultation with impacted Aboriginal communities and community meetings will be held and regular newsletters issued to update residents on the project and seek their input. Over the next several months, Bruce Power Alberta will also establish an office in the Peace Country to co-ordinate its consultation, technical studies, site evaluation and planning activities.

Unlike Energy Alberta, which had an agreement with Atomic Energy of Canada Limited to promote AECL's ACR 1000 design, Bruce Power Alberta has not chosen a specific reactor design for the site. Instead, it will consider the potential impacts associated with several of the world's leading designs, known as Generation III reactors. Bruce Power is taking a similar, technology-neutral approach in Ontario, where it is conducting another EA to determine if it will build new reactors at its Bruce site.

Bruce Power Alberta has the same ownership as Bruce Power in Ontario, being an all-Canadian partnership among TransCanada Corporation of Calgary, Cameco Corporation of Saskatoon and BPC Generation Infrastructure Trust, a trust established by the Ontario Municipal Employees Retirement System and based in Toronto. Duncan Hawthorne is the president and CEO of Bruce Power Alberta as well as of Bruce Power.

Darlington receives five-year licence

On February 28, 2008, the Canadian Nuclear Safety Commission awarded Ontario Power Generation a five-year licence for its Darlington nuclear generating station. As well as the power plant, the new operating licence also covers the Tritium Removal Facility on the same site.

Darlington's four 881 MWe CANDU pressurized heavy water reactors (PHWRs) had a capacity factor of almost 90% during 2007.

The new operating licence runs from 1 March 2008 until 28 February 2013, and includes extra conditions on which OPG must present a status report at future public proceedings in about two years. Some of the extra licence conditions concern changes to the organization of management at Darlington, and the re-qualification testing of some certified power plant shift staff.

Rabbit Lake Mine Back in Production

In early January, Cameco Corporation announced that its Rabbit Lake operation had resumed normal mining activities, well ahead of schedule, after sealing off the source of the water inflow.

In late November 2007, Cameco's Rabbit Lake underground mine experienced increased water inflow and mining was suspended. Cameco constructed and poured four concrete bulkheads in the first two weeks following the start of this event and continued grout sealing these bulkheads and the surrounding rock while waiting for the concrete to cure.

At the same time, the site crews were determined to locate the source of the water inflow and seal it permanently. An old exploration drill hole was identified as the potential source early on and Cameco used various techniques to locate and verify it. Site crews confirmed the source of the mine water inflow by injecting a dye into the drill hole. Then they successfully plugged the hole by installing an inflatable packer in the hole. Mining activities were then able to resume.

Bruce unit 5 record run

Unit 5 of the Bruce B station had run continuously for 520 days when it was shutdown on February 23 for an unplanned outage to repair a fuelling machine. It along with two other Bruce units had capacity factors over 93 percent in 2007.

In January 2008 the maximum power of Unit 5 was raised by three percent. This followed changes to the fuel-loading pattern that allows the limit to be raised from 90 to 93 percent of originally rated power.

Bruce Power's president, Duncan Hawthorne, noted that through improvements at Bruce B and restarting two units at Bruce A, output on the site had increased by more than 60 percent since 2001.

Bruce Unit 5 was returned to service on March 8.

EAs for OPG projects

In the fall of 2007 Ontario Power Generation applied to the Canadian Nuclear Safety Commission for a licence to prepare a site for a new nuclear power station on the property of its existing Darlington station. Under the *Environmental Assessment Act* such a licence requires an environmental assessment.

In January 2008 the Commission announced that it had decided to refer the application to the Minister of the Environment with a request that he establish a panel to review the environmental assessment.

At about the same time OPG submitted an Environmental Assessment (EA) Study Report to the CNSC on its proposed refurbishment of the Pickering B nuclear generating station.

The results of the assessment identified no significant residual adverse environmental effects of the proposed PNGS B Project, taking into consideration the identified in-design measures and feasible mitigation measures. The process now shifts to the CNSC, for preparation of an EA screening report, public review, and eventual CNSC hearings.

Proposed new Liability Act under review

After being in preparation for over a decade the federal government is actually expediting passage of legislation to amend and replace the *Nuclear Liability Act*.

Bill C-5, the *Nuclear Liability and Compensation Act, was introduced in early fall 2007,* passed second reading in the House of Commons and referred to the Standing Committee on Natural Resources for detailed review. Industry stakeholders have made submissions to the Committee for minor amendments. Nevertheless, on December 12, 2007, the Committee reported Bill C-5 to the House of Commons without amendment.

It is expected that the Bill will proceed quickly to third reading for adoption. Once adopted by the House, Bill C-5 will go to the Senate. Industry observers hope that this important legislation will be passed soon, definitely before an election.

Bill C-5 re-states the key principles of the liability regime established under the *Nuclear Liability Act* for damage caused by the occurrence of a nuclear incident in Canada, namely, that:

- The operator's liability is exclusive; that is, no person other than an operator is liable for damage caused within Canada; and
- The operator's liability is an absolute, strict liability requiring no proof of fault or negligence.

The most significant change is a massive increase in the maximum liability for operators from $75 million to $650 million. This increased liability will be reviewed at least once every five years by the Minister of Natural Resources and, if appropriate, the Minister would have the statutory mandate to increase (but not decrease) the maximum liability threshold by regulation.

(Interestingly, there has little media attention or public debate despite the fact that nuclear liability has been a major point of anti-nuclear groups in the past.)

Final steam generator lifted into Bruce A

During the first week of January 2008, the 16th new steam

generator was successfully lifted into Bruce A, completing one of the major elements in the project to restart Units 1 and 2. .

Using the massive crane that was brought in specifically for this job, crews carefully lowered the final 100-tonne vessel into place in Unit 1.

"This is a significant day for us and a symbolic one for many people in our community," aid Duncan Hawthorne, Bruce Power's President and Chief Executive Officer. "The need for new boilers was a big reason why Bruce A was prematurely closed in the 1990s. To see these new vessels in place reaffirms how times have changed and that our restart project is progressing well."

Each Bruce A unit has eight steam generators, which are essentially large boilers that create steam to turn the station's turbines and generate electricity. The replacement steam generators were manufactured in Cambridge by Babcock & Wilcox Canada and installed by SNC-Lavalin Nuclear. The first boiler was removed from Unit 2 in March 2007 and the first replacement vessel was installed in June.

The learning curve on the steam generator replacement program was steep and evolved to the point where crews performed two lifts on a single day in November. Prior to this project, there had not been a single steam generator lifted out of a CANDU unit anywhere in the world.

Bruce Power provides weekly videos and reports on the refurbishment on the "Bruce A Restart" section of its website: www.brucepower.com .

Draft agreement finalized for Romanian reactors

Cernavoda 2

In early March 2008 six European utility companies completed negotiations to partner with Romania's Nuclearelectrica SA in a joint venture to complete and operate two new units at the Cernavoda nuclear power station in Romania.

The six companies that will be developing and operating units 3 and 4 are: ArcelorMittal, CEZ, Electrabel, Enel, Iberdrola and RWE Power. Subject to Romanian government approval, the so-called Project Company is expected to be registered in May 2008..

The Cernavoda plant was originally intended to host five Canadian CANDU reactors of 633 MWe each. Construction on units 2-5 was halted in 1991 in order to concentrate on unit 1, which entered commercial operation at the end of 1996. It now provides 10% of the country's electricity. The government decided to resume work on unit 2 in 2000. After some upgrades during completion, unit 2 is rated at 655 MWe and began commercial operation in October 2007.

Cernavoda 3 and 4, both 750 MW CANDUs, will be a similar design to Cernavoda unit 2. The new units are slated to start up in 2014 and 2015, respectively.

AREVA and partners to proceed with Midwest Project

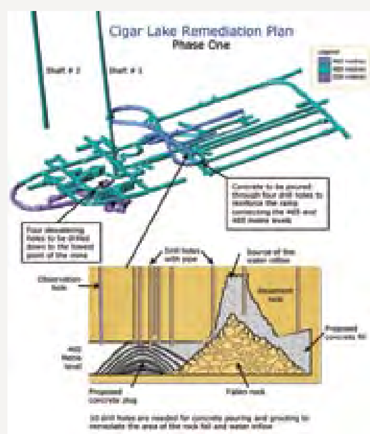
AREVA Resources Canada Inc. and partners have decide to proceed with the development of the Midwest Project, located 15 km west of the McClean Lake Operation.

The partners comprise AREVA Resources Canada Inc. (69.16%), Denison Mines Corp. (25.17%) and OURD Canada Co. Ltd. (5.67%). AREVA Resources is the operator of both McClean Lake and Midwest.

The Midwest Project involves draining part of the Mink Arm of South McMahon Lake in northern Saskatchewan to construct an open pit mine about 45 hectares in size (about 900 by 350 metres) and 215 metres deep. The ore will be trucked along a dedicated haul road to the McClean Lake mill for processing. The open pit mine will produce about 36 million pounds of U_3O_8 (14,000 tonnes of uranium). The total capital cost including mine development and the related McClean Lake mill expansion of about \$100 million will be approximately \$400 million.

Subject to regulatory approvals, site construction including the haul road, water treatment plant and other facilities could begin in mid-2009. Stripping of the rock over the ore would start in early 2010 with ore removal from mid-2011 through to 2013. The project will employ about 150 people and will support the operation of McClean Lake, which presently employs about 330 staff and 110 long-term contractors.

Cigar Lake remediation proceeding



Cameco Corporation has reported that significant progress has been made in the remediation work at the Cigar Lake uranium project.

Remediation work has been underway since October 2006 when a rockfall resulted in a flood of the underground development. Construction was about 60% complete at that time.

A concrete barrier in the area of the inflow has been constructed and a tunnel adjacent to the rockfall reinforced. This includes injection of cement into the rock around the area of the inflow to seal off the area. A test has shown that the seal is effective with no indication of plug deterioration throughout the six-day testing period.

There are a number of activities that must now take place before dewatering the underground development can begin, including an assessment to determine if depressurization, reinforcement or other precautionary measures are necessary in two other areas of the mine.

In addition to the technical work, we need to complete many of the corrective actions arising from the root cause investigation before applying for regulatory approval to dewater the mine.

An application to the Canadian Nuclear Safety Commission to allow dewatering of the underground development is planned for the first half of 2008.

Production startup is still not expected until 2011.

New President at Areva Resources Canada

In January 2008 Vincent Martin was appointed president and CEO of AREVA Resources Canada

Mr. Martin joined the COGEMA group, predecessor of the AREVA Group, in 1982 and held a number of management positions leading to his position as Operations Manager for the Mining Division of Hérault before joining AREVA Resources Canada Inc. in 1994 as Development Manager, Midwest Project. Mr. Martin was promoted to the position of Vice President Operations in 1997 and to Senior Vice President and Chief Operating Officer in 2001.

Born and raised in France, Mr. Martin graduated in 1980 from the École Nationale Supérieur des Mines de Paris. He currently resides in Saskatoon along with his wife and two sons. Mr. Martin has dual citizenship – Canadian and French. He was appointed Honorary Consul of France in Saskatoon in November 2007.

L-3 MAPPS to upgrade AREVA Simulators

L-3 MAPPS of Montreal, a subsidiary of L-3 Communications, has been awarded a contract from AREVA to upgrade three simulators with the incorporation of CATHARE, an advanced thermal-hydraulic calculation code used to study the behaviour of pressurized water reactors in accident situations.

L-3 will integrate CATHARE on AREVA's engineering simulators located at the AREVA Tower in Paris La Défense (France), which are used to perform plant engineering and emergency response training, operating procedures analysis and improvement, system design modifications, and preliminary safety analysis.

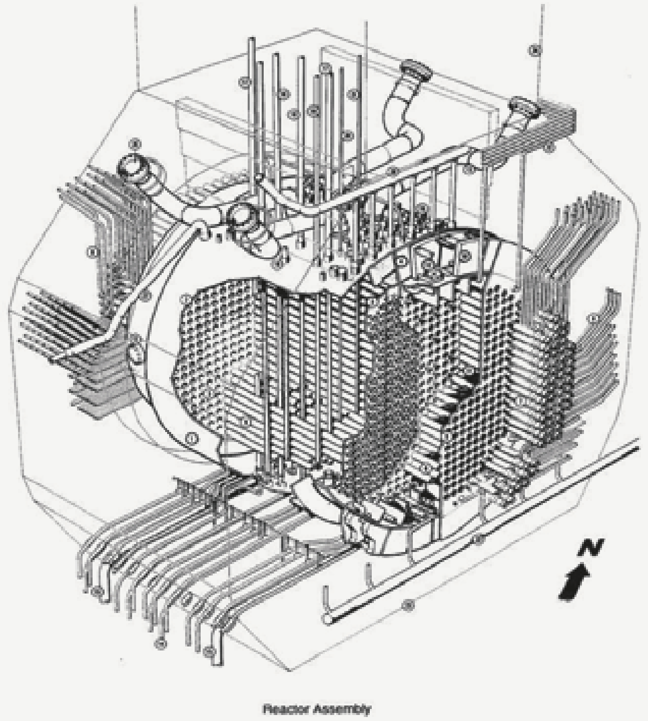
The three simulators represent the CP2 (900 MWe, 3-loop), DPY (1,300 MWe, 4-loop) and N4 (1,450 MWe, 4-loop) French-designed nuclear power plants. Through a previous collaboration with AREVA, both the CP2 and the DPY simulators operate on L-3's PC/Windows-based simulation environment. The N4 simulator will be rehosted by L-3.

Pressure tubes removed from Bruce 2

The retube team from Atomic Energy of Canada Limited has removed and compacted the last of the 480 pressure tubes from Bruce Unit 2 reactor early on March 13, 2008. This first-of-a-kind task, completed with remote controlled tooling in 87 days, involved multiple modifications to tooling and equipment to perfect the process.

The last two tubes were stuck and presented a major challenge. Manual tools were brought in from the Mock-up Building to complete the task.

Crews are now preparing the next series of tooling which is designed to release the 480 calandria tubes from their rolled joint connections to tube sheets on both ends of the reactor's core (calandria). Like the pressure tubes, the calandria tubes will be removed for replacement.



The reactor's 480 pressure tubes are located inside 480 horizontal calandria tubes. All are being removed for replacement in Units 1 and 2.

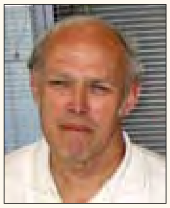
Flux detectors also removed

Bruce Power's Units 1 and 2 projects team successfully completed high-hazard work to remove two horizontal flux detectors from the Unit 1 reactor. The first removal on March 4,2008 was completed within a four-hour window with access to the reactor vault restricted until it was complete. The second removal on March 6 was accomplished in about 90 minutes.

The detectors are used to measure power within the reactor's core for the unit's secondary shutdown system. They will be replaced with interchangeable detectors later this year as part of the Units 1 and 2 Restart Project's Safety Improvement Plan.

CNS news

"From Here To There" – The View From The CNS President's Seat



"May You Be Blessed By Living In Interesting Times" (I have heard that defined as both a blessing and a curse) continues to be the prevailing theme during my term as CNS President.

During the past few weeks I have had the distinct pleasure of visiting the Chalk River Branch (25 February), the Ottawa Branch (28 February), and the University of Ontario Institute of Technology (UOIT) Branch (5 March). Interest and confidence in the nuclear resurgence was obvious everywhere. All three Branches are well run, energetic, and doing the CNS proud as they promote our organization and technology in their respective areas.

CNS Governance

The CNS Council gratefully received Drs. Murray Stewart and Robert Hemming's CNS Council Governance / Organization Task Force Report on 22 February 2008. A CNS Council Task Force Report Implementation Team was struck at the same meeting comprising of the Past President, Dr. Dan Meneley, 1st Vice President / President Elect Jim Harvey, 2nd Vice President Dr. Dorin Nichita, yours truly, and with Dr. Stewart acting as mentor to the Implementation Team.

Not wishing the Report's findings and recommendations to gather dust on our bookshelves, I proposed, and CNS Council approved, an aggressive plan to review, seek Council and Membership approval as required, and implement the recommendations for improvement where approved. The objective remains to bring CNS's operations more inline with the considerable challenges the nuclear renaissance is offering the CNS, while recognizing and building on our considerable current merits.

Constitutional / Bylaw improvements will be presented to the CNS Membership for their approval at this year's CNS Annual Meeting, Tuesday, 3 June 2008, at the CNS Annual Conference in Toronto. My thanks to all involved with this exciting and future enhancing project.

CNA Seminar

The recent Canadian Nuclear Association (C.N.A.) Nuclear Industry Seminar 2008, Ottawa, 27 – 29 February 2008 was excellent. The seminar presented an interesting high-level overview of the increasing need for nuclear energy to play an important role in Canada's future, and emphasized that the need for action to ensure this will indeed be the case is now.

For those unable to attend in person I strongly recommend that you invest in our future by reviewing the many excellent thought-provoking papers presented. These are available on the CNA web site, www.cna.ca, Annual Seminar, 2008 Annual Seminar Presentations.

"**Four Companies To Decide Ontario's next Nuclear Plant**" the early March 2008 newspaper article was entitled. While there seems to be little doubt that nuclear energy must play a significant role in our future, getting the right nuclear on time and on budget is the challenge. We must all treat every job we do in this industry as though the future of the industry depended on it, which in reality it does.

During my recent CNS Branch presentations I have been reviewing the status of the current renaissance in Ontario, the progress to date, and the short term plans for the future. Even though Ontario's 14,000 MW revitalization project is one of the biggest undertakings ever, anywhere, it still only maintains the status quo capability for future electricity generation in Ontario.

I for one am concerned that we are relying too heavily on yet unproven aggressive renewable energy and aggressive conservation. Yes, we should be doing more to promote and prepare for greater roles for these technologies. But like a large ship at sea, such changes happen slowly and take a great deal of time and effort to develop and implement. Too much is on the line to not rely more on the proven assets we have: safe, green, reliable, and cost effective nuclear energy. These have been proving for the last forty years that they can do the job.

Over long periods of time, such as the life cycle of nuclear station approvals, design, constructions and commissioning, some changes are simply unavoidable, regardless of the skill and resources used to try to anticipate them. While we must continue to strive to meet all our commitments, I believe that we tend to be too hard on ourselves when tough cost and schedule objectives are not entirely met. We must all recognize that we are doing a great job and providing good value to our shareholders and customers in our envelope stretching endeavours.

There are great opportunities in this industry now and for generations to come. We need everyone involved to do their best in everything they do to fully realize this promise. This includes promoting our industry to friends, acquaintances, our elected representatives, and the public whenever the opportunities arise. We have been silent far too long. The opportunity for nuclear is here again, and this time we must not let our technology, ourselves, and our future down.

Eric L. Williams, P. Eng
canoe.about@bmts.com

Memories from the Staff Hotels

AECL Hotels Home to Thousands by Al Bancroft

From the earliest days of AECL's atomic energy project at Chalk River, the staff hotels in Deep River housed employees of the contractors who built the town, and later, the staff of NRC/ AECL and Crawley and McCracken caterers. There were also nurses, teachers, shopkeepers and other personnel who kept the plant and town running. During the 60s and 70s, Ontario Hydro trainees en route to nuclear generating stations stayed in Forest Hall for periods of six months or so.

Residents, perhaps 5000-10000 over a 40-year period, were mainly young, single, energetic and eager for adventure. The hotels (Camp Dormitories, Staff Hotel, Annex and Forest Hall) were active from 1945 until 1985, when they were finally sold or demolished. With about 500 residents during peak occupancy, there were ample opportunities for having fun, making friends and finding mates. And this was exactly what we did - in a big way! Now, we are left with brains full-to-bursting with great memories and are recording them to share with others.

In March 2007, a Deep River group of former residents started to:

- compile a register of all people who lived in the hotels (the list reached 1300 in November); and to
- gather photographs from everybody who can find them (we have about 700 from about 80 contributors) and stories (just passed 140).

This information is all from our collective memory bank! There are no AECL or Staff House Club records to be found.

A *Gathering of Former Residents* is planned to be held in Deep River on **Saturday August 2, 2008,** during the Summerfest 2008 extravaganza.

The book we are preparing, ***Memories from the Staff Hotels, Deep River, 1945-1985*** is being distributed by LoonsNest Books and Gifts in Deep River nd sold at cost of $35 per copy, plus shipping and handling, if requested.

The deadline for placing orders is May 1, 2008. Copies will be printed only for those who place orders and pay in advance. As a volunteer organization we cannot accept the financial risk of printing copies on speculation.

To order, please contact Debi Adams, Proprietor, LoonsNest Books and Gifts by mail at P.O. Box 1469, Deep River, ON, K0J 1P0, by email at loonsnestbooks@hotmail.com, by telephone at 613-584-9532 or by fax at 613-584-9531. Payment can be made by personal cheque payable to The LoonsNest, by Mastercard or Visa, or by cash or debit in the store. Copies of the book should be available in the store starting May 17th and can be picked-up there, or at the Summerfest reception for former residents on August 2, 2008.

Please help us to reach any former resident who you think may be interested in purchasing this book. Send a copy of the information sheet to your friends and acquaintances, or contact them.

More details are on the website at http://bright-ideas-software.com/staff_hotel. Or contact

Pat Meadowcroft at meadow@magma.ca or PO Box 1222, Deep River, ON, K0J 1P0, or Al Bancroft at pinept@magma.ca or PO Box 1355, Deep River, ON, K0J 1P0.

WE WANT TO SEE YOU, PLEASE COME!

Staff Hotel, 1955 *photo by Al Okazaki*

"Badge-Draw" Winners at the 2008 January CNS Fuel Technology Course

At the end of the CNS Fuel Technology Course, on January 27, 2008, 11 prizes were awarded by random draw from among badges returned by Course attendees.

The winners:

- Trish Laurie, of AECL, and Robert Kozeluh, of OPG, each won a CNS multitool
- Thanuja Janathasing, of AECL, and Jean-François Côté, of Hydro-Québec, each won a book
- Jay Harris, of Bismark State University, Brian Grohs, of OPG, Chris Toole, of Atlantic Nuclear Services Limited, and Cory Linton, of UOIT each won a CNS sweatshirt
- Dana Martin, of OPG, won a CNS golf shirt
- Tod Smythe, of OPG, and Massimo di Ciano, of AECL each won a complimentary CNS membership good to end of 2008

Congratulations to all the winners!

Gagnants de prix au tirage des porte-insigne au cours de la SNC sur la technologie du combustible, janvier 2008

À la fin du cours sur la technologie du combustible, le 27 janvier 2008, 11 prix ont été tirés au sort parmi les porte-insigne retournés par les participants au cours.

Voici les gagnants des prix:

- Trish Laurie, de l'EACL, et Robert Kozeluh, d'OPG, ont chacun gagné un ensemble d'outils de la SNC
- Thanuja Janathasing, de l'EACL et Jean-François Côté, d'Hydro-Québec, ont chacun gagné un livre
- Jay Harris, de Bismark State University, Brian Grohs, d'OPG, Chris Toole, d'Atlantic Nuclear Services Limited, et Cory Linton, de UOIT, ont chacun gagné un chandail sport de la SNC
- Dana Martin, d'OPG, a gagné une chemise de golf de la SNC
- Tod Smythe, d'OPG, et Massimo di Ciano, de l'EACL, ont chacun gagné un adhésion gratuite à la SNC jusqu'à la fin de 2008

Félicitations à tous les gagnants!

Branch News

Alberta, *Duane Pendergast*

Paul Hinman, Gary Lewis and Bryan White (chair of the Education and Communication Committee) participated in the Mighty Peace Teachers Convention on March 6,7,8.

Whitecourt City Council and Woodland County are hosting two debates this spring. Speakers have been identified. The first pits Paul Gunter versus George Bereznai on April 4 and 5. The second features David Schindler and Patrick Moore. Paul Hinman has requested observer status at these debates as the city and county have suggested that non-residents are not invited.

One more new member, Bill Olsen, from Fairview joined CNS in January. Bill is a retired professor of Physics from University of Alberta. Welcome Bill.

Chalk River, *Blair Bromley*

Since the beginning of the year the following events have occurred.

January 24, 2008, Wayne Thompson, Deep River, was the guest speaker for the first CNS Branch Seminar for 2008. He spoke about the History and Status of Search and Rescue in Canada. It was an interesting talk, but unfortunately only a small crowd attended.

January 11, 2008 was the deadline for the Chalk River Branch's 5th Annual Essay Contest on the Applications of Nuclear Science and Technology. The essays written this year were quite good. Unfortunately, participation was less than hoped for, with only four entries from two schools. We are considering changing the format and focus of the essay contest to turn it into a scholarship application for graduating high school students entering university, with fewer, larger prizes (perhaps two prizes at $1000 each).

The Chalk River Branch of the Canadian Nuclear Society hosted its 3rd Annual Dinner/Seminar on February 25, 2008 at the Bear's Den in Deep River. Eric Williams, CNS President, presented the current status of the Bruce A Units 1 and 2 Refurbishment Project and Bruce Power's vision for the next thirty years. The seminar was open to the public.

3rd Annual Dinner/Seminar. Shown left to right are: Syed Zaidi, Jeremy Whitlock, Bryan White, Eric Williams, Marcel Heming, Blair Bromley, Ragnar Dworschak, Uditha Senaratne, Chris Canniff, and Jintong Li.

Among our plans for 2008 we propose to establish a scholastic award for graduating high school students in Renfrew County. We are planning on targeting three high schools with two prizes of $100 each per student, per school.

We welcome new CNS members Rick Blimkie and Martin Klukas.

Jintong Li is leading the effort on promoting our 2nd Annual Poster Contest on the Applications of Nuclear Science and Technology. The deadline for poster submissions is May 16, 2008.

Golden Horseshoe, *Dave Novog*

The GH branch has been active in meeting with McMaster science and engineering staff on potential involvement and participation in young-people and women's science activities on campus. In particular the ideas that have come up are a support of a "Women in Today's Nuclear" speakers night involving undergraduate females meeting with high ranking and successful females from the nuclear industry and being jointly held with the WIE speakers night. This has the potential to reach 30 to 60 young female engineers and provide perspective on the present and future opportunities in the nuclear industry.

The second event targets young people within the girl-guides organization during the annual McMaster girl guides day. About 120 young people (and parents) from the local community attend the event and the GH branch is proposing funding the BBQ lunch this spring. We plan on having marketing material available as well as signage that the lunch is sponsored by the CNS.

Ottawa, *Mike Taylor*

On 24 January, the branch held a successful lunchtime meeting at which the speaker was Dr Satyen Baindur who spoke about "Nuclear Hydrogen Production: Safety Issues in a Nuclear/Thermochemical Context". The main focus of this talk was on the potential use of nuclear power to generate hydrogen for use on the Alberta oil sands.

On February 28, CNS president Eric Williams spoke about his experiences over more than 30 years in the nuclear field.

Two members of the Branch Executive attended a meeting of the Local Organising Committee preparing for the up-coming World Nuclear University Summer Seminar to be held in Ottawa in July/August this year.

Members of the Branch staffed the CNS stand at the 2008 CNA Seminar, February 27-29.

Sheridan Park, *Adriaan Buijs*

In the reporting period the Sheridan Park Branch had one seminar, by Jeremy Whitlock from AECL: "CANDU Non-Proliferation and Safeguards: A Good Story Seldom Told". The seminar was very well received by a large audience. The new site entry procedures at Sheridan Park did not cause any major inconvenience to visitors from outside AECL.

News from the Education and Communication Committee

by Bryan White

The Education and Communication Committee budget for 2008 includes the purchase of a number of Aware Electronics RM-80 Geiger-Müeller detectors to support science education initiatives.

This detector interfaces with a personal computer via a serial communications port. The Windows software program can be configured to record count data files and display the data graphically in real time with alarm features. To date, three detector systems with USB interfaces have been received. One has been sent to the Sheridan Park Branch to be used in presentations at schools. Two have been sent to the Alberta Branch. A further seven detector systems are scheduled for delivery this spring.

On February 27th, concurrent with the CNA Annual Seminar, the CNA provided a workshop for science curriculum coordinators from across Canada as part of its development of a nuclear science curriculum program. The CNS provided three Aware detector systems for the workshop to demonstrate their potential for use in the classroom. One Aware system was included in the CNS exhibit at the Annual Seminar. Subsequently, the ECC has been contacted by some of the participants.

The Alberta Branch of the CNS organized an exhibit booth at the Mighty Peace Teachers' Convention in Grande Prairie, March 6-7. The ECC assisted Paul Hinman (Edmonton) and Gary Lewis (Fort MacMurray) with this initiative. Peter Lang and Bryan White helped staff the booth. As the CNS was unable to borrow a CANDU dummy fuel bundle, Peter Lang made his own facsimile of a Pickering Bundle.

The CNS booth at Mighty Peace Teachers' Convention in Alberta. L to R: Gary Lewis, Peter Lang, Paul Hinman

The new revision of the potassium-40 ("NoSalt"® …) fact sheet is available on the CNS web site Education page.

Canadian Nuclear Achievement Awards

Each year, the Canadian Nuclear Society joins with the Canadian Nuclear Association to present awards to individuals and groups that have contributed significantly to the Canadian nuclear program.

A booklet describing the various awards and their criteria was mailed to all on the CNS and CNA mailing lists in January 2008.

Read the booklet or go to the CNS website: **www.cns-snc.ca** for a description of the various categories and criteria.

Everyone in the Canadian nuclear program is urged to look around and identify persons or groups that should be honoured.

Then contact Bob Hemmings, Chair of the CNS / CNA Honours and Awards Committee at: **michelineandbob@sympatico.ca**

Membership continues to grow

as of February 20, 2008 – 1229! – jusqu'au 20 février 2008

We would like to welcome the following new members, who have joined the CNS in the last few months, up to 2008 February 20.

Nous aimerions accueillir chaudement les nouveaux membres suivants, qui ont fait adhésion à la SNC ces derniers mois, jusqu'au 20 février 2008.

Danya Al-Haydari, Hardy Stevenson and Associates Ltd.
Arjan Arenja, Bruce Power
Eric Arsenault, New Brunswick Community College, Saint John
Roopinder Kaur Aulakh, AECL
Peter Baumgartner, AECL
Rick Blimkie, AECL
Michael Bonaventura, UOIT
Andrew Brooks, McMaster University
Warren Choi, UOIT
Alex Lay-Lum Chong, UOIT
Tyler Cosgrove, UOIT
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Kristine Drew, AECL
Julian P. Duncan, AECL
Tarek Elghawaby, Carleton University
Ayman Faddah, University of Windsor
Marina Freire-Gormaly, University of Toronto, Eng. Science
Petre Georgescu, R&D National Inst. For Metals & Radioactive Resources - INCD MRR
Mohamed Salah Geweida, UOIT
Trevor M. Greer, K Tool and Die
Michal Gulinsky, UOIT
Tara Hargreaves, Radiation Safety Institute of Canada
In-Seob Hong, AECL
Jeff D. Hunt, UOIT
David T. Hutchson, Black & McDonald
Richard Ireland, UOIT
Thanuja Janathasing, AECL
Martin H. Klukas, AECL
Brandon MacDonald, UOIT
Lenora E. Makin, UOIT
Paul Marko, Hitachi Canada Ltd., Power & Industry Division
Yi Liao Meng, UOIT
Omar Mohamed Noor, UOIT
Asaad Yamani Mohammed, UOIT
Hoda Motazedi, UOIT
Jonathan Newberry, Atomix Nuclear Services Incorporated
Cam T. Ngo, AECL
William Olsen, University of Alberta
Shannon M. Paret, AECL
Sonia Vijay Parikh, UOIT
Hemal V. Patel, UOIT
Philipp Puetz, Carleton University
Mohammad Jawad Qureshi, UOIT
Abrar M. Shaikh, UOIT
Ahmed F. Shalabi, Canadian Nuclear Safety Commission
Todd A. Smythe, Associate Scientist
Jay Snell, Stern Laboratories Inc.
Chris Toole, Atlantic Nuclear Services Ltd.
Vince A. Wohler, RAY-BAR Engineering Corp.
Yina Zhang, University of Western Ontario

Canadian Nuclear Society
Société Nucléaire Canadienne

10th International Conference on CANDU Fuel

Delta Ottawa Hotel and Suites,
Ottawa, Ontario
2008 October 5-8

leading the Renaissance

CALL FOR PAPERS

The Canadian Nuclear Society (CNS) cordially invites you to submit a paper for the tenth International Conference on CANDU Fuel, to be held at the Delta Ottawa Hotel and Suites, **Ottawa, Ontario, 2008 October 5-8**. Canada's capital shall play host to this premier event for CANDU Fuel. This conference provides the best forum for CANDU Fuel experts from around the world to share experience, present innovations, discuss research, renew old acquaintances and network with their peers.

We Invite Papers Relating to all Aspects of CANDU Fuel Including the Following Topics

Fuel Performance: Station experience, post-irradiation examination (PIE) studies/techniques, fuel behaviour (normal operating conditions and extended burnup);
Fuel Safety: Licensing issues, accident analysis, fission-gas release, fuel behaviour and experimental simulation;
Design and Development of Fuel and Fuel Cycles: Modifications to designs, quality assurance in fuel design and development, MOX, slightly enriched uranium, recovered uranium, Thoria cycles, CANFLEX™, low-void reactivity, environmental, economical and societal implications of fuel cycles;
Fuel Model Development: Predictive capability on thermal, mechanical, irradiation and fission-gas-release behaviour under either normal operating or accident conditions;
Manufacturing & Quality Assurance: Fuel manufacturing experience, advances in manufacturing & inspection technologies and quality assurance;
Fuel Management: Fuel management schemes, fuel physics analysis and operational problems;
Fuel Bundle Thermalhydraulics: CHF and CCP assessments, reactor aging, crept pressure tube and fuel simulations;
Spent Fuel Management: Handling technology, spent fuel storage and disposal approaches, in-storage fuel behaviour;
History of CANDU Fuel: Developments of CANDU fuel from design, testing and manufacture viewpoints, implementation of manufacturing quality assurance standards, development of fabrication technologies for CANDU fuel, and development of computer codes demonstrating fuel performance.
Human Factor Engineering, Criticality Safety and other safety, work place and environment related papers.

Abstract & Paper Submission

Interested authors should submit a <300-word summary/abstract indicating the planned content for the session chosen from the above list. Summaries must be received by **May 30th, 2008.** Authors will be notified of the acceptance of their submissions by **July 16th, 2008**. Final copies of the papers must be received by **September 1st, 2008**. All accepted papers would be issued as part of the Conference Proceedings. Summaries should be submitted in electronic form to fuel2008@cns-snc.ca or in hard-copy to:

Holly Hamilton (stn. 63)
Chalk River Laboratories
Chalk River, Ontario
Canada
K0J 1J0
Tel: (613) 584-3311, ext. 6049; Fax: (613) 584-8214

The organizing committee is looking forward to receiving your abstracts.

Canadian Nuclear Society
23rd Nuclear Simulation Symposium
"The Next Generation of Simulation Tools"

2008 November 2-4
Ottawa, Ontario, Canada

Call for Papers

The Canadian Nuclear Society is organizing its 23rd Nuclear Simulation Symposium in Ottawa, Ontario, Canada, 2008 November 2-4.

The objective of the Symposium is to provide a forum for discussion and exchange of information, results and views amongst scientists, engineers and academics working in various fields of nuclear engineering.

The scope of the Symposium covers all aspects of nuclear modelling and simulation, including, but not limited to:

- Reactor Physics
- Thermalhydraulics
- Safety Analysis
- Fuel and Fuel Channels
- Computer Codes and Modelling

Deadlines

- Receipt of full papers: 2008 June 2
- Notification of acceptance: 2008 July 14
- Receipt of revised full papers: 2008 Sept. 15

Guidelines for Papers

Although no limit will be applied, a length of approximately 10 pages is suggested for a typical paper. Papers should present facts that are new and significant or represent a state-of-the-art review. Proper references should be included for all closely related published information.

NOTE
For a paper to appear in the Symposium Proceedings, at least one of the authors must register for the Symposium by the deadline for receipt of revised full papers
(2008 September 15)

Submission Procedure

Submissions should be made electronically, preferably in MS Word format, through the Symposium electronic submission system at:

https://www.softconf.com/starts/CNS2008/

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General information regarding the Symposium

http://www.cns-snc.ca/simulation2008.html

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Note to Authors

CALENDAR

2008

June 1 - 4 — **29th Annual CNS Conference and 32nd CNS/CNA Student Conference**
Marriotte Eaton Centre
website: www.cns-snc.ca

June 8 - 12 — **American Nuclear Society 2008 Annual Meeting**
Anaheim, California
website: www.ans.org/meetings

June 8 - 12 — **ICAPP 2008 – 2008 International Congress on Advances in Nuclear Power Plants**
(Embedded in ANS 2008)
Anaheim, California
website: www.ans.org/goto/icapp08

July 21 - 23 — **EPRI 27th Steam Generator NDE Workshop**
Palm Desert, California
email: blancaster@epri.com

Sept. 3 - 5 — **CNS CANDU Reactor Safety Course**
Kincardin, Ontario
website: www.cns-snc.ca

Sept. 7 - 11 — **PSA 2008 – International Topical Meeting on Probabilistic Safety Assessment and Analysis**
Knoxville, Tennessee
contact: George Flanagan
email: flanagangf@ornl.gov

Sept. 14 - 19 — **Physor 2008**
Interlaken, Switzerland
website: www.physor2008.ch

Sept. 20 - 26 — **IYNC 2008 – International Youth Nuclear Congress**
Interlaken, Switzerland
website: www.iync.org

Sept. 30 - Oct. 4 — **NURETH 12 – International Topical Meeting on Nuclear Reactor Thermal Hydraulics**
Pittsburgh, Pennsylvania
website: www.nureth12.org

Oct. 5 - 8 — **10th CNS International Conference on CANDU Fuel**
Delta Hotel, Ottawa, Ontario
website: www.cns-snc.ca

Oct. 13 - 18 — **16th PBNC – 16th Pacific Basin Nuclear Conference**
Aomori, Japan
website: www.pbnc2008.org

Oct. 19 - 24 — **IRPA 12 – 12th International Congress of the International Radiation Protection Association**
Buenos Aires, Argentina
website: www.irpa12.org.ar

Nov. 2 - 4 — **CNS Simulation Symposium on Simulation Methods in Nuclear Engineering**
Marriotte Hotel, Ottawa, Ontario
website: www.cns-snc.ca

Nov. 16 - 18 — **8th CNS International Conference on CANDU Maintenance**
Metro Toronto Conference Centre and Intercontinental Hotel, Toronto, Ontario
website: www.cns-snc.ca

2009

May 12 - 15 — **EIC Climate Change Technology Conference**
McMaster University
Hamilton, Ontario
email: jacksond@mcmaster.ca

May 31 - June 2 — **30th Annual CNS Conference & 33rd CNS/CNA Student Conference**
Calgary, Alberta
website: www.cns-snc.ca

CNS Membership Renewal (for Those who Forgot)

If for any reason you have not yet renewed your CNS membership for 2008, **now is the time to do it!** You certainly don't want your membership to lapse! You need to renew **now** to keep receiving the Bulletin and other CNS communications. If you have lost your renewal form, you can simply copy one from the CNS website at www.cns-snc.ca. **Thank you!**

Also, consider the convenience of automatic renewal. The CNS Office can renew your membership each year in good time, at the earlybird rate. If you are interested, indicate it when you send in your renewal form.

Note: Your individual CNS ID number is shown on your renewal form, and it also appears on the CNS membership card which you receive every year. Keep your card and ID number handy – it is proof of your membership, and you are asked for it when you register to a CNS Conference or Course!

Ben Rouben
Chair, Membership Committee

Renouvellement d'adhésion à la SNC (pour ceux qui ont oublié)

Si pour une raison quelconque vous n'avez pas encore renouvelé votre adhésion à la SNC pour 2008, **c'est le moment de le faire !** Vous n'aimeriez certainement pas perdre les bénéfices de votre adhésion ! Vous devez renouveler **maintenant** pour continuer de recevoir le Bulletin et les autres communications de la SNC. Si vous avez perdu votre formulaire de renouvellement, vous pouvez en copier un du site Web de la SNC, à www.cns-snc.ca. **Merci bien !**

Veuillez aussi noter que le renouvellement automatique est très commode. Le bureau de la SNC peut renouveler automatiquement votre adhésion chaque année, et vous profiterez toujours des prix réduits de renouvellement. Si ça vous intéresse, veuillez l'indiquer quand vous enverrez votre formulaire de renouvellement.

Ben Rouben
président du comité d'adhésion

N.B. : Votre numéro de membre de la SNC apparaît sur votre formulaire de renouvellement, ainsi que sur votre carte de membre, que vous recevez chaque année. Veuillez garder votre carte et votre numéro de membre à portée de la main – c'est votre preuve d'adhésion, et on vous le demande quand vous vous inscrivez à une conférence ou à un cours de la SNC !

Pump and Circumstance

by Jeremy Whitlock

Once upon a time, there lived a princess named Enaaru who was both beautiful and strong. It was said of Enaaru that both her land and her people made her strong, and that she made them strong in return.

"Where Enaaru goes," the people said, "so goes health and happiness."

Even as the people prospered, however, there was apprehension, for it was long prophesied that upon Enaaru's fiftieth birthday her fortunes would fail and darkness would cloak the land. Many, including Enaaru herself, did not believe this prophecy, thinking it a whimsy of the elders.

The years passed, Enaaru grew older, and so did her land and people. It seemed that everyone walked a little slower, bent a little lower, and talked with reverence of the old days when all was young and fresh. Still, Enaaru kept her health and beauty, and the people kept their devotion.

In a land not far from Enaaru's, there was at the same time a sorceress named Sienessee who, it was said, held dominion over the sky, the land, and the water. This did not concern Enaaru's people because these things were all strong, as was Enaaru, and therefore (so it was reasoned) Sienessee must like Enaaru and her people. To ensure this, the people made offerings to Sienessee, and these were accepted though nobody ever saw the sorceress in person.

It came to pass that as Enaaru approached her fiftieth birthday, her father, King Enaarkhan, took her aside to talk. He told her how fifty years earlier he had yearned deeply for a daughter, and how a mysterious voice came to him one night in a dream. The voice said that he would have a daughter - a princess - but that a twin daughter would also be born to him, who would be a sorceress. The voice told him that the two girls must never know they were sisters until their fiftieth birthday, and that his people would only be happy if the daughter sorceress was happy, for the two girls would draw their power from each other.

Enaarkhan then told how the daughter sorceress became jealous of Enaaru's beauty and strength as the two grew older, and how she eventually left to live in a new land, which she magically filled with many people. Still the daughter sorceress grew ever more jealous. She erected towering walls around her land but she could not escape the thought of Enaaru.

That sister, Enaarkhan whispered, was Sienessee.

Enaaru was shocked to learn this news, and began to worry about the prophecy of her fiftieth birthday. The day passed without incident, but soon afterward, even as the songs of celebration still echoed in the hills, a tempest indeed enveloped the land. All became darkness, and the people cried that the prophecy had come true. The crops failed, snows covered all, and Enaaru's beauty and strength seemed to bleed from her with each passing day.

Then one morning, Sienessee appeared to the people and exclaimed, "I am your princess! See how powerful I am! See how weak your Enaaru is!" She commanded everyone to wear Google goggles, and these showed the people their ailing princess.

The people grew afraid. As the days passed and Enaaru grew weaker some cried out, "How could we have gambled our health and happiness on one person so weak! What fools we were!"

Over the roiling, sulphurous seas came legions of onlookers, wearing Google goggles and chanting "Kill Enaaru! Cut her throat! Spill her blood!"

At that moment King Enaarkhan gathered strength, for he remembered what the voice in his dream all those years ago had said: "They will draw their power from each other".

He commanded the people to remove their Google goggles, and as the people did, they saw not a dying princess or an all-powerful sorceress, but two tired women: sisters and kindred spirits.

"I love you both, and you are both my daughters", said the wise Enaarkhan. Sienessee was chastened, and the weak Enaaru reached out to her.

"You will live and work together," Enaarkhan continued, "and all will be prosperous once more in our land."

And so it was, for many years afterward, that Enaaru and Sienessee worked as one to ensure the health and happiness of the people, and all was both beautiful and strong.

The End.

2007-2008 CNS Council • Conseil de la SNC

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CNS WEB Page - Site internet de la SNC

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

http://www.cns-snc.ca