CANADIAN NUCLEAR SOCIETY

Bulletin

DE LA SOCIÉTÉ NUCLÉAIRE CANADIENNE

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- 50th Anniversary of Nuclear Power Demonstration
- CNA Conference and Trade Show
- Commentary on Radiation Levels for Evacuation
- Fukushima – One Year On

Fukushima – One Year On

The live television coverage on March 11, 2011 of the Great Japan Earthquake and ensuing tsunami shocked the world as we watched in disbelief seeing people run to higher ground, cars float out of control, ships capsize and houses sweep away. Entire villages were claimed by the sea and more than 20,000 people are lost forever. The sea wall protecting the Fukushima Daiichi nuclear power plant crumbled under the mighty force of water. This double disaster had now set up a chain of events that would change the world.

Taking advantage of the situation the anti-nuclear "experts" wasted no time appearing on live media to promote their agenda, leaving an ill-prepared industry to seemingly cringe in defence. To make matters worse, the Chairman of the USNRC, who was ill advised by staff running computer models, proclaimed that the Unit 4 spent fuel cooling pond had gone dry and a forth meltdown was imminent. Confusion and chaos ensued because information from credible sources was not forthcoming, or conflicted with information gleaned from so-called "experts". In response, more than 200,000 people were displaced from their homes. Adding to confusion, US nationals living in Japan were evacuated to 80 km, or 60 km further than Japanese citizens, which did not help a government trying to instil calm.

The response from National regulators was immediate. The CNSC activated its Emergency Operations Centre and staffed it 24/7 (see Terry Jamieson's extended abstract in this issue of the Bulletin). In many countries the licensing of new builds was suspended while operators conducted a so-called "Stress Test" which is an in-depth review of how the plant would respond to extreme natural phenomena.

The response in Germany was rather remarkable. Eight plants were ordered to shut down immediately and all remaining plants will be shut down permanently within a decade. John Ritch, Director General of the World Nuclear Association is quoted in World Nuclear News as saying:

"Countries like Germany will soon demonstrate the economic and environmental irresponsibility of allowing politicians to set important national policies in the middle of a panic attack."

He added:

"In contrast, many national leaders who soberly reviewed their energy strategies have reaffirmed the conclusion they reached before Fukushima: that nuclear power is a uniquely reliable and expandable source of low-carbon energy that can be safely used to meet clean-energy need."

Germans, in the name of environmentalism, will now burn more fossil fuel and import nuclear generated electricity from its neighbours.

There is no doubt that the triple meltdown at Fukushima was a very serious event. However, it is important to realize that not one person, including the valiant workers on site, has been harmed by radiation. There has not even been a case of radiation sickness. This important point is often overlooked in all the media frenzy.

Now, one year later, more than 80,000 people in Japan remain displaced from their homes. The criterion for displacement is based on receiving a dose of 20 mSv per year and decontamination efforts are underway to allow residents to return. The IAEA advised Japan "not to go overboard" with decontamination efforts and to focus its resources on "hot spots" where it would have a significant risk reduction benefit. Furthermore, the 20 mSv criterion is disputed. Many believe that the evacuation is no longer necessary (see related Commentary by Dr. Cuttler in this issue of the Bulletin).

Was the triple meltdown at Fukushima preventable? The tidal barrier was designed for the largest tsunami recorded since 1896. However, the Jorgan tsunami of 869 was even larger than what struck Fukushima. This finding was reported in 2001 by palaeontologists who examined tsunami deposits found well inland, which is an example of the kind of information that international standards require designers to consider. If this known data had been considered, then a larger sea-wall might have been built or emergency backup equipment moved to higher ground.

The bar of nuclear safety has been raised once again.

In This Issue

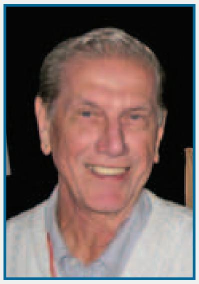
This year marks the 50th anniversary of Canada's first commercial nuclear generated electricity with the successful start-up of **Nuclear Power Demonstration**. (Shown on cover page.) Fred Boyd provides an interesting account of its early development of what became the forerunner of the successful fleet of **CANDU™** reactors.

We also include a report on the **CNA Conference and Trade Show**. Jerry Cuttler provides a commentary on the controversial radiation dose criterion used for evacuation with a re-print (by permission from **Radiation Research** journal) of Daniel Billen's review of the "**Negligible Dose**" controversy in Radiation Protection. We also note the first anniversary of the **Fukushima** accident and we include Terry Jamieson's extended abstract on the **CNSC response** to the disaster.

There is a commentary by Don Jones on **Wind on the Grid** and its impact on nuclear, as well as some technical papers, general and CNS News, and of course, Jeremy Whitlock's view of **Life at Fifty** in Endpoint.

Enjoy! Comments and letters are welcome.

From The Publisher



The Society

After about five years of discussion the Council of the Canadian Nuclear Society has finally established the position of Executive Director to oversee the total operation of the Society. *(See the official announcement in the CNS News section.)* The initial appointment goes to Ben Rouben, but on a very part-time basis. In his role as Executive Administrator over the past several years, again part-time, Ben has been involved in many of the activities of the Society. He will now shed some of the specific ones to be able to address the larger issues.

A major factor in the delay of creating the position was the question of whether or not the Society could afford it. The largest part of the CNS income comes from the conference and courses it holds. Except for the Annual Conference these vary considerably from year to year, meaning that the Society's income also varies markedly. For example, in 2011 the CNS held or sponsored four significant conferences resulting in a relatively large excess revenue over expenses. However, for 2012, there is just one large conference other than the Annual one. (That is the "Steam Generators to Controls" one to be held in Toronto in November). The result is a predicted large deficit for 2012.

It is unrealistic to expect Dr. Rouben to solve this problem in the short term. The inherent characteristic of the Society's governing structure with a 25 member Council (including executive) and the continued uncertainty of the Canadian nuclear program present ongoing challenges. Nevertheless it is recognized that there is potential for the CNS to grow in numbers and fields of discipline, which, in turn will lead to more opportunities for its programs.

Another positive development comes from two active members of the CNS Council, Jacques Plourde and Juris Grava. They have proposed (and Council endorsed) an "Operating Utilities Engagement Plan". Associated with that vision is a process to coordinate the activities of two of the Society's divisions – Nuclear Operations and Maintenance and Design and Materials – which are the ones most focussed on the operating nuclear plants.

They have set themselves an ambitious program of activities over the spring to meet with senior officials of the utilities operating nuclear plants and some of the major companies that support them.

Finally, don't forget the CNS Annual Conference, being held in Saskatoon, at the invitation of the Premier of Saskatchewan, June 10 – 13, 2012.

The Canadian and World Nuclear Scene

Editor Ric Fluke has commented on the one-year anniversary of the tragic events of March 11, 2011 at Fukushima, Japan.

As he noted and as summarized by Terry Jamieson, the Canadian Nuclear Safety Commission did an exemplary job in covering the event in detail, issuing orders to nuclear plant operators, and communicating with the public. We are fortunate to have such a capable regulator overseeing the whole range of nuclear activities in the country. It is ironic, however, that the regulator has been the best, sometimes only, communicator to the public on nuclear matters.

Worldwide, similar actions were taken in all of the countries with nuclear power. Despite the very vocal outcry from anti-nuclear groups most of those countries have decided to continue their nuclear power programs.

On the domestic front the federal government issued its official invitation for "Expressions of Interest" in operating the AECL Nuclear Laboratories. It has been clear for some time that the government was concerned about the costs associated with the laboratories, although accepting its responsibilities for historic and legacy wastes.

It is understood that at least three consortia are interested. Given the deadline of the beginning of April for those submissions it is possible that some decision will be made by the time of the CNS Annual Conference.

Although not in a position to operate the laboratories the CNS Council decided to make a submission emphasizing the unique capabilities of the laboratories and their importance to Canada.

Refurbishment remains in the news. Bruce Power has announced that, after a long, extensive and difficult refurbishment of Units 1 and 2 of the Bruce A station, Unit 2 is expected to be restarted this spring, with Unit 1 to follow in the summer. Congratulations. OPG has issued four-year contracts for planning of the refurbishment of Darlington. And, the CNSC has renewed the Operating Licence for the Point Lepreau station which will allow it to restart later this year.

Correction: In my appended note in the last (December 2011) issue I incorrectly implied that the Rutherford CD sent to CNS members was only about his work at McGill in the early years of the 20th century. The CD actually contains three parts, which includes the periods before and after Rutherford's time at McGill.

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~ Cover Photo ~

Aerial view of Nuclear Power Demonstration (NPD) generating station with the training school in the foreground.

Photo courtesy of AECL

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

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Canadian Nuclear Association 2012 Annual Conference and Trade Show

CNA Annual Event Continues Successful Format

by FRED BOYD

Over 600 participants, speakers, delegates, exhibitors and students, converged on the Westin Hotel in Ottawa, February 22 to 24, for the 2012 CNA Annual Conference and Trade Show. The theme for the conference was *"Leadership through Innovation"*

While the event officially opened with a reception on the evening of February 22, it was preceded by two workshops and a Career Development Seminar for the 100 (plus) students who had been sponsored by several CNA member organizations. The workshops were on *"Regulatory Affairs"* and *"Talking about Radiation"*. The latter was over-subscribed.

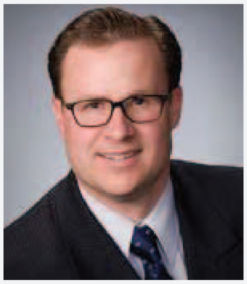
The large number of exhibits testified to the optimism of the many organizations associated with, or wishing to become involved in, the Canadian nuclear program. Many organizations had more than one booth, with several devoted to recruitment, indicating that employment opportunities exist for qualified (mostly young) people.

During the opening reception a special event was held – the presentation of the prestigious Ian McRae Award to Gerald (Jerry) Grandey, recently retired CEO of Cameco Corporation. *(See separate report on that presentation.)*

The conference proper began with breakfast on the next morning, at which **Wayne Robbins**, Chief Nuclear Officer at Ontario Power Generation and Chairman of the CNA, provided an overview of the conference and remarks about the Canadian and world nuclear scenes and activities of the Association. He noted that 2012 marks the 50th anniversary of nuclear power in Canada, *(See separate article on the 50th anniversary of NPD (Nuclear Power Demonstration) whose reactor started-up in April 1962.)*

Referring to the Fukushima tragedy in Japan he noted the quick action of the Canadian Nuclear Safety Commission (CNSC) and its subsequent report showing that Canadian plants were very safe. He mentioned several developments such as: the Environmental Assessment for new build at Darlington; the program for a Low and Intermediate Waste repository on the Bruce site; the completion of the Restart program at Bruce A; the proposed refurbishment of the two CANDU units at Cernovoda, Romania; the agreement between Canada and China for the export of uranium and the recent approval in the USA for two new nuclear plants.

He concluded by mentioning new CNA initiatives, including: Twitter, an information section in the Globe & Mail, and active discussions with the CNSC on regulatory development and reform.



After delegates moved to the adjacent conference room, CNA President, **Denise Carpenter**, introduced an unscheduled speaker, **Rob Norris**, a Minister in the Saskatchewan government with four portfolios – Advanced Education; Innovation; Saskatchewan Power Corporation and the Uranium Development Partnership program.

Norris mentioned Saskatchewan's early involvement in nuclear matters with reference to Dr. C. J. Mackenzie, first president of Atomic Energy of Canada Limited and Dr. Harold Johns, developer of one of the first Cobalt 60 therapy machines. He noted the Canadian Light Source cyclotron and the new Canadian Centre for Nuclear Innovation associated with the University of Saskatchewan. Partners in that Centre are welcome, he announced.

The first scheduled speaker was **Jay Ingram**, co-host of the science program, *Daily Planet* on the Discovery TV channel, whose topic was *Science in the Popular Media.*

The popular media tends to be negative, Ingram commented, showing a few cover photographs from prominent publications. Members of the public observe reported facts through their previous beliefs. Individuals, he said, are generally against government rules except when they are directed towards business. Most people have a "confirmation bias" and additional information will not change their opinion. However, he noted, people tend to become more accepting of nuclear power when they learn more about it.

To a question, he suggested ignoring newspaper columnists. They are opinionated and any response will be ignored.

Tom Mitchell, President and CEO of Ontario Power Generation, brought the industry perspective on the disaster at Fukushima, Japan, from his role as Chair of the Post-Fukushima Commission of the World Association of Nuclear Operators (WANO).

The tsunami which followed the massive earthquake on March 11, 2011, killed an estimated 25,000, swamped over 500 square kilometres of land and displaced tens of thousands residents. At the four-unit Fukushima Daiichi plant it destroyed all of the back-up systems. That eventually caused melting of the fuel in the three reactors that had been operating.

The nuclear industry around the world immediately reacted, he noted... In Canada, the Canadian Nuclear Safety Commission set up a 24/7 team to follow the event and requested the operators of all of the Canadian nuclear plants to re-examine their safety systems against extreme external events.. He noted that all Canadian reactors have two separate shutdown systems and multiple back-up power sources. WANO also reviewed the event and sent out directives to all of its members around the world.

Mitchell said he did not feel that the event will significantly affect the world nuclear program and, hopefully, not the position of the Ontario government.

Next was **Michael Binder**, President and CEO, Canadian Nuclear Safety Commission. With a series of often humorous slides he summarized the ten most important events of 2011 for the CNSC and the likely ten challenges of 2012.

He began with his "trade-mark" slide of the CNSC as "Canada's nuclear watch dog" which included a picture of a hound wearing glasses.

For 2011 his list was, in ascending order; CNSC / AECB 65th anniversary; Initiation of Participant funding; Uranium spill on ship Altona; Licence renewal of Gentilly 2; Licence renewal of Chalk River Laboratories and NRU; Integrated Regulatory Review; Government fiscal restraint; Bruce steam generator proposed shipment; Darlington environmental assessment; CNSC response to Fukushima.

For 2012 his list was: Fukushima review; Deep Geological repository; New build; Refurbishments; Uranium projects; Regulatory updates; Transportation; Mission-focussed research; Government regulatory reform program; COMMUNICATION.

The morning closed with an extended Panel Discussion on *Innovative Methods of Communicating Science*, moderated by Kay Ingram. The panelists were: **Ted Harwell** of the Desert Research Institute; **Toby Heaps**, CEO of the Corporate Knights magazine; and **Susan Brissette**, former president of WiN Canada and chair of the Communications Committee of WiN Global.

Much of the discussion centred on the role of social media. Brissette noted that WiN International now has 80 country organizations. WiN Canada has created a Facebook page which has already had a large number of hits.

At the lunch a video of **Joe Oliver**, Minister of Natural Resources, was presented, in which he expressed his regrets for being unable to attend in person. He spoke specifically about the sale of the engineering group of AECL to SNC Lavalin and noted the new company, Candu Energy Inc., had already received a major contract from Argentina associated with the refurbishment of the Embalse reactor. He stated that his department is assisting in negotiations with Jordan, Romania and China.

Regarding the AECL Laboratories at Chalk River he announced the invitation for "expressions of interest" to manage the site. "Restructuring AECL is a critical step to enhance the nuclear program while reducing the government's [financial] exposure", he stated.

Then, Tom Mitchell introduced the luncheon speaker, **Patrick Lamarre**, Executive Vice-President, Global Power, SNC-Lavalin Group and head of SNC Lavalin Nuclear,

The Fukushima event emphasized the international aspect of nuclear energy, he stated, and mentioned his participation in the Canadian contingent to the special meetings of the International Atomic Energy Agency. He then turned to the creation, and first four months, of Candu Energy Inc. Most of the former AECL staff have been retained, he commented, and the new owners are impressed with their abilities, which, he opined, were equal to any similar group in the world.

He commented that the special features of the CANDU design and its suitable size for many grids makes it a winning formula. Noting that he had been part of the group associated with the Prime Minister's recent visit to China, he stated that the Chinese were especially interested in the ability of CANDU to use recovered uranium from their many LWR units. On "new build" he mentioned some potential markets and noted the number of refurbishments likely in the near future. The new company will also be exploring service contracts for non-CANDU units, he said.

In closing he commented that Ontario must make a decision on new build. The industry [much of it in Ontario] can not stand by forever, he asserted in closing.

To a question, Lamarre explained the relationship between SNC Lavalin Nuclear and Candu Energy Inc. The former will do the typical SNC Lavalin role of balance of plant while Candu Energy will concentrate on the nuclear island.

The first speaker in the afternoon session was **Kathryn Jackson**, Senior Vice-President and Chief Technical Officer with Westinghouse Electric, who spoke primarily about the company's development of a 250 MWe modular PWR design.

That size is easier for utilities to accommodate, she said, referring to commercial US power companies which are having difficulty raising the large capital costs of large plants. She noted also that many of the coal-fired plants that are being retired are of that size. The entire plant will be modularized, she said, with the modules being built in factories. To emphasize the difference in scale she showed a slide indicating that up to 25 reactor vessels of the 250 MWe size could fit into the one for their AP 1000 design.

Turning to the AP 1000 design, which is being built in China, she used the phrase "simply safe". It can cope with a total station black-out, she asserted. The Chinese are turning to modular construction, she commented, and then noted that for much of the construction; 8 hours at the site can be equalled by 3 hours in a pod and 1 hour in a factory.

In closing she commented that up to now the USA and Canada were the leaders in technology. That will not continue, she warned.

After the break there was a 90 minute panel discussion entitled *Nuclear Innovation: Bright Ideas to Keep the Lights On*. The panelists were: **Doug Richardson**, CEO, General Fusion; **Michael Lees**, President, Babcock & Wilcox Canada; and **Bob Prince**, CEO, Hyperion Power Generation. The moderator was **Marc Brouillette**, a Partner of the large consulting company Secor Group od Montreal.

General Fusion is based in Burnaby, B.C. It is developing a fusion machine using both magnetic confinement and inertial confinement using lasers. Hyperion Power Generation, which is based in California, is developing small (25 MWe) nuclear plants using modular design and employing a fast reactor cooled by liquid metal. B & W Canada is the well-known manufacturer of most of the steam generators in Canadian nuclear power plants, located in Cambridge, Ontario.

Leading off the discussion, Lees defined innovation as developing something new, and mentioned the small reactors being developed by B & W Canada's sister company in the USA. It comes from people motivated by curiosity and supported by encouragement. Prince referred to the national laboratories in the USA where, he said, there is a "dog-eat-dog" atmosphere in competing for [government] funding. That led to an extended but inconclusive conversation on the relative roles of national laboratories and private organizations.

The day ended with a two hour reception in the trade show.

Friday morning began with breakfast at which **Michael Shermer** spoke about *Why People believe Strange Things.* Shermer is the founding publisher of Skeptic magazine, executive director of the Skeptic Society and a monthly columnist for Scientific American.

He began with the phrase "I want to believe", which, he said, is a universal feeling. We all have a "belief engine" he said, which seeks patterns and connects dots. He used the word "patternicity" to describe the tendency to see, and believe in, patterns. This is very prevalent in baseball where superstition is widespread. Increased dopamine in the brain enhances patternicity, he stated. If the level is just right it enhances creativity, if too high it leads to madness.

There are many illusions about probability, he said. That leads to misperceptions which are not supported by statistics and people confirm their initial bias.

Three presentations focussed on scientific innovation completed the Conference program.

First was **Terrance Ruddy**, Director of Nuclear Cardiology at the University of Ottawa Heart Institute and Head of Cardiology and Nuclear Medicine at the University. His topic was *Innovation in Nuclear Medicine.* He spoke about the collaboration between the university and the isotope company Nordion which is leading to alternative isotopes for use in patient imaging and research into new therapies for heart diseases. His groups are also partnering with AECL on the effect of low-doses of radiation on nuclear workers.

John McDougall, President of the National Research Council described the extensive changes in the mandate and structure of that national laboratory under the title *Changing the Culture in Canadian Research and Innovation.* The goal, he said, is to redesign NRC to improve Canada's innovation performance. He spoke of three agendas – focus; sustainability; communication.

Five key decisions have been made:

1. Develop a new culture and set of values
2. Adopt a RTO model
3. Create "flagships", programs and portfolios to replace the current many Institutes
4. Apply a common business process throughout the organization
5. Create a new management structure

The organization will be more mission-oriented, he said, with more customer funding. The "flagships" are:

- Printable electrons
- Sustainable profitable wheat
- Bio-composite materials
- Conversion of algae to value-added products

He said they expect to end up with about 35 major programs. Each proposal must go through several steps of evaluation from concept to implementation. The outcome of all of the changes, he said, will be:

- A business-like organization
- An innovation engine
- A key instrument for sustaining and growing our standard of living and quality of life.

The final presentation was by **Bob Walker**, President and CEO, AECL Nuclear Laboratories, whose title was: *Innovation Science and Technology for a Strong Nuclear Industry*. He began with the quip from the renowned base-ball player, Yogi Berra, that "the future ain't what it used to be".

What is the new AECL? he asked rhetorically. First, he said, there are the world-wide public policy priorities:

- Reduce deficit
- Economic development
- Increase public health, safety and security

Science and technology are enablers towards these objectives, he stated.

The new AECL will have three primary roles:

- Adviser to and agent of the federal government
- Enabler of business innovation [related to nuclear]
- Generator of highly qualified people

The science and technology priorities for AECL Nuclear Laboratories are:

- Radiation and the public
- CANDU technology
- Nuclear operation
- Standards and regulations
- Nuclear security
- Future energy options
- Environmental stewardship

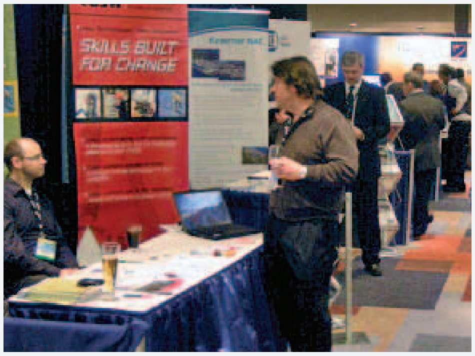
There was closing luncheon at which **Denise Carpenter**, President and CEO of the CNA made some closing remarks.

She thanked all the remaining participants and her staff, all of whom, she said, helped in the organization and functioning of the conference and trade show. She asked all attendees for input for future events.

The conference was supported by a large number of sponsors, exhibitors and supporters.

Primary sponsors were: Cameco; Tetra Tech; Ontario Power Generation; AECON Nuclear; Westinghouse Electric Canada; AECL; AMEC; Bruce Power; CNSC; Energy Solutions; KPMG; General Electric Hitachi; Power Workers' Union; Ian Martin Group; Babcock & Wilcox Canada; Areva.

Scenes from the Conference



Ian McRae Award presented to Jerry Grandey

The Ian McRae Award, one of the most prestigious Canadian Nuclear Achievement Awards, was presented on the first evening of the 2012 Canadian Nuclear Association Annual Conference and Trade Show in Ottawa, February 22.

The recipient was **Gerald (Jerry) Grandey**, former CEO of Cameco Corporation.

Established in1976, by the Canadian Nuclear Association the *Ian McRae Award is* named in honour of Ian F. McRae, who was the first president of the Association and, at that time, Chairman of the Board of Directors of the Canadian General Electric Company Ltd.

The guidelines for the award read, in part, as follows:

The criteria include but are not limited to the candidate's contribution to the general advancement of nuclear energy in Canada through such fields of activities as management, administration, public service, medicine and communication.

The citation for Jerry Grandey reads:

Throughout his distinguished career in Canada' nuclear industry, Mr. Grandey earned the reputation as a well-respected, influential leader who helped shape nuclear advancement on a global scale. He is being recognized for raising the nuclear profiler to a higher level along with Canada's reputation as a world leader in nuclear safety. He has been a strong supporter and vocal advocate for the industry through the dedication of his personal time and resources at Cameco Corporation to support the national efforts of the Canadian Nuclear Association.

The ceremony took place during the opening reception of the Conference and part of it suffered from the background sounds of those apparently unaware of the award event.

Denise Carpenter, President of the CNA, opened the presentation ceremony by remarking it was a great way to start the conference. Next was a video presentation of some of the highlights of Grandey's career and other activities. Carpenter noted that Grandey had flown in from Hawaii, where he was on vacation, just for the award ceremony. She then introduced Rob Norris, a Minister in the Saskatchewan government with four portfolios – Advanced Education; Innovation; Saskatchewan Power Corporation and the Uranium Development Partnership program. Norrtis spoke briefly about Grandey's achievements during his tenure at Cameco and his pleasure in his many dealings with him over the years.

Wayne Robbins, Chairman of the CNA and Chief Nuclear Officer at Ontario Power Generation, presented Grandey with the small sculpture that is the symbol of the award.

Then, Hany Michael, Senior Vice-President, Tetra Tech, co-sponsors of the reception, presented Grandey with a large painting of a Canada goose, symbolizing the wilderness of northern Saskatchewan, the location of Cameco's Canadian uranium mines.

In his response, Grandey referred to his coming from Hawaii but emphasized his pleasure at being in Ottawa despite the difference in weather.

He spoke of his many dealings with government officials especially just after joining Cameco in 1993 when he was recruited to be involved with negotiations with Russia in the decommissioning of many of their nuclear weapons. Those dealings went on for six years, but the program ended with agreement to dismantle 18,000 weapons and putting the derived enriched uranium into the civilian program without overly disrupting the nuclear fuel market.

In closing he commented that the world's nuclear program will overcome the negative effect of the event in Japan a year ago. Fukushima will not leave a lasting legacy, he asserted, the benefits of nuclear will prevail.

Cameco was formed in 1988 as a merger of two Crown corporations, the federal Eldorado Nuclear Limited and the Saskatchewan Mining Development Corporation. It was partially privatised in 1991 and became fully public in 2002. Gerald Grandey was appointed as Chief Executive Officer in 2003 and retired in 2011.

Hany Michael of Tetra Tech presents Jerry Grandey with a painting entitled "Soaring" during the Ian McRae award ceremony at the Canadian Nuclear Association Conference in Ottawa, February 22, 2012.

NPD, the first CANDU

by FRED BOYD

Foreword: This article concentrates on the early decision-making and design process that resulted in Canada's first nuclear power plant. That small plant introduced most of the basic concepts that became the essence of the CANDU design.

Of the many reactor concepts proposed decades ago for nuclear power plants, CANDU is one of the few designs of nuclear power reactors that has become successful worldwide. There are now 18 operating CANDU nuclear units in Canada and eight in other countries. In addition India has 18 operating pressurized heavy water reactor (PHWR) units operating and three under construction, all based on an early CANDU version.

The beginning of this success can be identified with the start-up, 50 years ago this spring, of the small Nuclear Power Demonstration (NPD).

At 2:40 a.m. on April 11, 1962, heavy water was pumped into the reactor calandria and at a level very close to that calculated the neutron detectors indicated that a sustaining chain reaction had been achieved. The NPD reactor had gone critical.

A modest-sized crowd, representing station staff, designers, physicists, regulators and others, were squeezed along the far wall of the control room watching this historic event. When the reactor was stabilized at a very low power, that group gathered around the control desk for what has now become a classic photograph. (Fig.1)

Just two months later, at 1:31 a.m. on June 11, 1962, NPD sent the first Canadian nuclear generated electricity into the Ontario grid. That event was marked by a much more subdued celebration.

Alan McCarthy, R, is shown at the controls of NPD when it first delivered power to the grid, 1:31 a.m., June 4, 1962, with Bill Lawson, shift supervisor, L, and Lorne McConnell, station manager looking on.

At the time of the start-up the plant was called NPD – 2 because it was the second design of the small demonstration unit. It was that second design which initiated the unique features of the CANDU line of nuclear power reactors. The short title will be used in the rest of the article.

Background

While the start-up of NPD marked the beginning of Canada's nuclear power program it was also the culmination of much study, analyses and design that began with the creation of the Montreal Laboratory in 1942. In December of that year a small number of British and European nuclear scientists moved to Canada because the wartime conditions in the UK were not amenable to their work. They were established in a new building of the University of Montreal which led to the name Montreal Laboratory and set up as a division of the National Research Council.

The Montreal Laboratory team developed the underlying theories and a conceptual design of a reactor using natural uranium in a heavy water moderator. That led to the NRX (Nuclear Research Experimental) research reactor.

Following the choice in 1944 of Chalk River as the site for a nuclear laboratory, a small reactor named ZEEP (from Zero Energy Experimental Pile) was built. When it first went critical on September 6, 1945, it was the first reactor outside the USA. At the same time the large (40 MWth) NRX reactor was under construction. It started operation on July 22, 1947.

In December, 1950, federal government approval was given to build a much larger research reactor, NRU (National Research Universal). Design began immediately but NRU did not achieve first criticality until July 22, 1957, exactly 10 years after NRX first achieved criticality. Its neutron flux was the highest flux of any research reactor in the world at that time. Of particular note, NRU incorporated technology to enable the reactor fuel to be changed while the reactor remained in full operation. This ability to refuel without shutting down the reactor was a world "first" and was, subsequently, to play an important role in the success of the CANDU power reactors.

In early 1952 Atomic Energy of Canada Limited (AECL) was created as a crown corporation to take over the assets and responsibilities of the Atomic Energy Project. The minister in charge, C. D. Howe, appointed four senior Canadian utility representatives to AECL's first Board of Directors. One was Richard Hearn, the Chief Engineer of the Hydro Electric Power Commission of Ontario (HEPC, to later become Ontario Hydro). Hearn was attracted to the concept of nuclear-generated electricity because Ontario was running out of undeveloped hydraulic capacity.

Near the end of 1953, HEPC and AECL agreed to

Members of the operating staff, scientists, engineers and others associated with NPD, Canada's first nuclear power plant, gathered around the control desk following the initial start-up of the reactor in the early hours of April 11, 1962 for this historic photo.

proceed with a jointly-funded feasibility study aimed at defining a possible pilot nuclear power plant. Given the experience with NRX the heavy water moderated, natural uranium fuelled, reactor concept was considered to be the first choice.

In late 1954 the AECL Board approved, in principle, proceeding with the design and construction of a small demonstration power reactor. Seven private Canadian companies were invited to submit proposals for this work. AECL undertook to provide necessary nuclear-related technical data to the companies developing proposals and also undertook responsibility for subsequently supplying nuclear fuel, heavy water, and appropriate expert personnel from its staff to the envisaged project.

Meanwhile, certain key features of the design concept were being firmed up by a study team at the Chalk River Laboratories, headed by Harold Smith of HEPC. These included the basic specifications for a reactor pressure vessel, the use of heavy water as reactor coolant as well as moderator and the use of on-power refuelling (which had been pioneered in the NRU design). The envisaged use of a pressure vessel to contain the reactor core was a natural outgrowth of the NRU reactor design. By placing an NRU-type core inside a thick-walled steel pressure vessel and pressurizing the heavy water coolant and moderator to about 100 times atmospheric pressure, the operating temperature of the coolant could be increased to about 300 degrees Celsius, suitable for power production.

A further key feature of the selected design concept was the use of an alloy of zirconium as the fuel cladding material since it is the only metal relatively transparent to neutrons. By alloying with small quantities of other elements, a highly satisfactory family of zirconium-based fuel cladding materials had evolved, called "Zircaloy". Although the original development of Zircaloy was by the U.S. Atomic Energy Commission and its contractors, testing had been done in NRX which made the technology available to the Canadian program.

Early in 1954, AECL received proposals from the private companies interested in undertaking the design and construction work. The chosen bidder was Canadian General Electric (CGE), because of its broad-based engineering and manufacturing capability and its offer to contribute significant funding to the program. Attention now turned to securing a Canadian utility partner. HEPC's offer to participate through providing the conventional portion of the power plant and undertaking to purchase the steam from the nuclear portion to power the conventional portion was accepted by AECL and, subsequently approved by the federal cabinet on March 23, 1955.

Design team established

An initial design team, numbering less than 30, was assembled in mid-1955 in a relatively new building at CGE's works in Peterborough. Some were from the joint study team; others were recruited from within AECL and CGE. The initial accommodation was primitive by today's standards.

Other members of the joint study team stayed at Chalk River to work on the conceptual design of a much larger unit (200 MWe) intended to follow the smaller unit.

A site for NPD was chosen near HEPC's Des Joachim hydraulic generating station on the Ottawa River which was close to AECL's Chalk River laboratory and had access to power transmission lines.

By October, 1955, a key technical decision had been taken; to switch from uranium metal as the fuel material to uranium dioxide which had shown several superior properties during testing carried out for the U.S. navy in the NRX reactor at Chalk River. These superior properties included excellent dimensional stability during irradiation in the reactor core and much greater corrosion resistance.

Initial NPD team at CGE, Peterborough, summer 1955.

Change of design

While work on the detailed design of NPD proceeded, the team at Chalk River reached a conclusion of major importance regarding the larger reactor; that it should be of the pressure tube type rather than of the pressure vessel type. This conclusion was driven by the fact that the pressure vessel required for the larger reactor would be far bigger and heavier than could be manufactured in Canada with any existing facilities. Even the smaller NPD vessel had been ordered from the U.K. for this reason. The pressure vessel required for the larger reactor would have had a diameter of about fifteen feet and would have weighed several hundreds of tons.

A further major consideration was the fact that by early 1957, contractors for the U.S. Atomic Energy Commission had established a viable fabrication process for pressure tubes made of Zircaloy, intended for the Hanford New Production Reactor. Testing of those tubes had also been done in NRX. The availability of zirconium pressure tubes meant that a practical pressure tube reactor could be built.

This major conclusion then posed a vital question. Should NPD continue as a pressure vessel reactor or should it be redesigned as a pressure tube reactor? Work had already begun on the site and, as noted earlier, a pressure vessel was being built in Scotland. While changing the fundamental design would involve a major project delay and additional costs, in March, 1957, the AECL Board made the historic decision to redesign NPD as a pressure tube reactor.

In six months the CGE design team, which had grown to about 150 (including draftsmen who, at that time, were an important part of the team) produced a comprehensive Design Study. The new conceptual design incorporated all of the fundamental aspects of what became to be known as CANDU.

One of the early questions was that of core orientation. Should the reactor core be vertical, as in the case of NRX and NRU, or would a horizontal orientation prove superior? The horizontal orientation was selected for reasons related to the desire to have refuelling of the reactor at full power to avoid the need for reactor shutdowns.

It had already been decided to make the fuel in relatively short bundles. Therefore, a "push-through" refuelling arrangement was desired, since it would avoid the need to tie the individual fuel bundles together.

Fuelling Machines

The fuelling machines presented a major mechanical design challenge. A key aspect of the NPD design was still to have on-power fuelling. This meant closures on each end of the fuel channel which could be opened and reinserted by remotely operated fuelling machines. The machines would also need to be able to accept fuel from new fuel ports at each end of the reactor vault and discharge irradiated spent fuel to transfer ports for discharge to the spent fuel bay. And, because the heavy water coolant was extremely expensive, leakage had to be prevented.

The scheme chosen called for two identical fuelling machines to be employed, one temporarily connected to each end of the pressure tube being refuelled. One of the machines would push in the desired number of new fuel bundles, displacing the same number of spent bundles into the other machine. These basic features of the refuelling arrangements have been retained in all subsequent CANDU reactors.

The initial NPD fuelling machine used internal hydraulic drives to preclude the problem of seals.

There were a number of "teething" problems with the original fuelling machines and the first successful on-power refuelling took place November 24, 1953. The system was not fully in service until 1964.

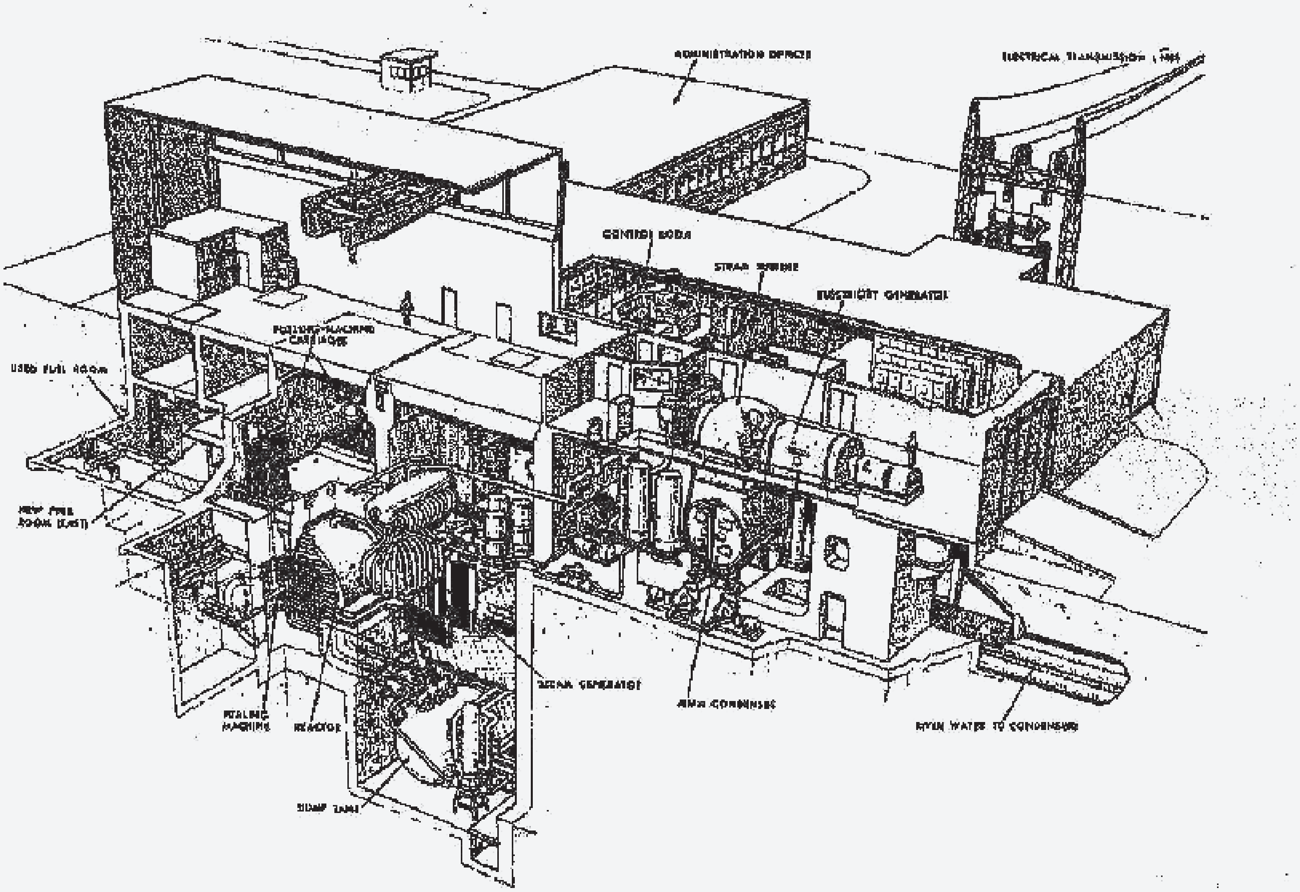
The original machines were replaced in 1969 by ones using an alternative arrangement developed for the prototype Douglas Point plant which involving ball screws and special shaft seals. This Mark II design was installed in 1969 and operated successfully for the balance of the life of the plant. Subsequent CANDU fuelling machines have used this concept.

Reactor

While it had been decided to have the reactor vessel horizontal to accommodate the fuelling system, this still left the questions of reflector and control mechanisms. After comparing the advantages and disadvantages of heavy water, light water and graphite, light water was chosen and has remained a feature of CANDU designs.

There were 132 fuel channels with Zircaloy coolant (pressure) tubes of 8.25 cm. diameter surrounded by aluminum calandria tubes of approximately 10 cm diameter. Each coolant tube accommodated nine fuel bundles.

For control it was decided to use moderator level, a



A schematic drawing of the NPD station.

concept that was not followed for subsequent CANDU designs. The heavy water was held up by air pressure in a U tube arrangement under the calandria. For shutdown, releasing the pressure allowed the heavy water moderator to drop quickly. As a safety feature, the valves controlling the air pressure were triplicated and operated on a two out of three basis. This allowed individual valves to be tested during operation, a concept that continues today.

Fuel

The fuel bundle chosen was approximately 50 cm. long with seven elements of approximately 2.5 cm/ diameter. (All dimensions were in inches.) Wire wrapping was used to separate the elements and enhance mixing of the coolant.

Although the basic fuel bundle concept remains, over the years the design of CANDU fuel has evolved markedly.

Safety

A notable feature of NPD is that there was no containment building. For the original pressure vessel design it had been decided to place the vessel in a hole in the rock and that hole had already been excavated at the time of the design change. A decision was made to place the new (NPD 2) reactor in the same hole, which had to be enlarged to accommodate the fuelling machines. The rock would act as a containment feature.

A unique arrangement was proposed to release the steam pressure in the reactor vault that would result from a large primary system pipe failure. A large passageway was proposed that would be sealed off by a glass wall that would be detonated, releasing the steam. A gate would fall to close the passage as soon as the pressure wave passed. Although the passageway was constructed the overall system was not completed largely because of occupational safety concerns for workers in the area.

Licensing

When AECL was created in 1952 the Atomic Energy Control Act, that had been passed in 1946 (one of the first in the world), was modified to transform the Atomic Energy Control Board (AECB) from an overall government supervisory body to primarily a regulatory one. Although the Act did not bind the Crown, the participation of HEPC provided the basis for the AECB to license the plant.

In 1956, the AECB had only one professional staff who was largely involved in security and international affairs. The Board had established a Reactor Safety Advisory Committee (RSAC) to review the research reactor being built at McMaster University. The chairman was George Laurence, a senior director at Chalk River, who had been the senior Canadian at the

Montreal Laboratory. Laurence had already become known for his pioneering work on the objectives and principles of reactor safety, resulting from his study of an accident to the NRX reactor in 1952. The Board asked the RSAC to review NPD.

In early 1958, the NPD team prepared a "Preliminary Hazards Report" which consisted of one volume of about 300 pages. The report proposed a risk-based approach which had been pursued by Laurence and others. Although it did contain analyses of a number of possible failures, notably breaking of the primary system piping, those analyses would be considered simplistic against today's safety analysis standards.

The RSAC convinced the AECB to engage a technical specialist to assist it. That was done in December 1958. Laurence was appointed the first full-time president of the AECB in 1961 and immediately hired three more staff members. (The Canadian Nuclear Safety Commission, which replaced the AECB with the passing of the Canadian Nuclear Safety Act in 2000, now has a staff of about 800.)

Training facility

NPD became the basic training centre for the expanding Ontario Hydro nuclear program. To accommodate the growing numbers of trainees and the training staff, a new building was erected on the NPD site (as shown on the cover photograph). The NPD Training Centre contributed greatly to the success of the rapidly expanding Ontario Hydro nuclear program in the 1960 to 1980 period.

A concluding comment

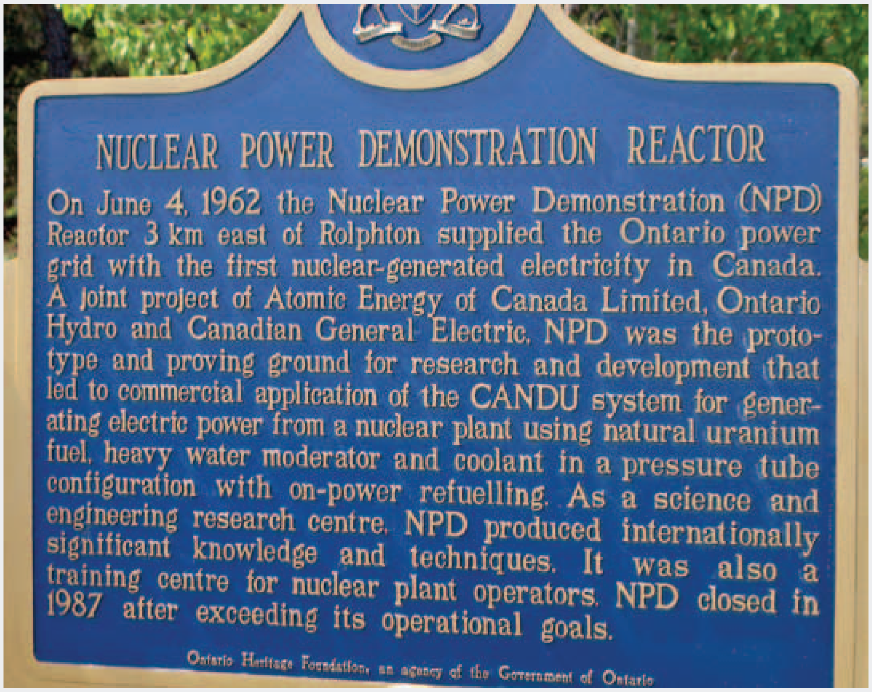
NPD was to enjoy a successful operating life of 25 years, providing invaluable experience to later designs and serving for many years as a vital training facility for later generations of Ontario Hydro operating staff needed for the new commercial power stations. NPD was taken out of service in 1987 when its early-generation pressure tubes had reached the end of their service life. By this time, NPD had more than fulfilled its original intended purpose and the cost of retubing the reactor could not be justified in view of its small (20 MWe) electrical generation capacity.

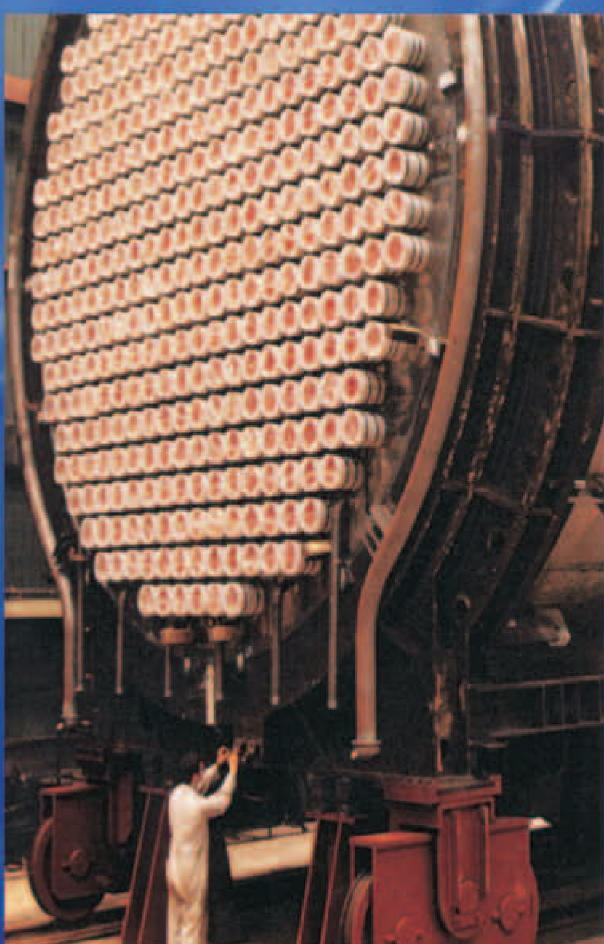
The design of NPD incorporated many of the features that have been retained in successive versions of the CANDU concept, a testimony to the inventiveness and capabilities of the members of the relatively small design team who were supported by an enlightened management and a licensing system that concentrated on a risk-based approach.

Historic Plaque erected decade ago

On June 1, 2002 a historic plaque was erected on Ontario's Highway 17 close to the road that led to NPD located on the shore of the nearby Ottawa River and about 20 km west of Deep River. That was to mark the 40th anniversary of the first power from NPD. The plaque was erected by the Ontario Heritage Foundation which is an agency of the province. The Canadian Nuclear Society was the official sponsor through an initiative of Jeremy Whitlock.

The photograph shows the plaque.





Commentary on the Appropriate Radiation Level for Evacuations

by JERRY M. CUTTLER, Cuttler & Associates Inc., Mississauga, ON Canada

This commentary reviews the international radiation protection policy that resulted in the evacuation of more than 90,000 residents from areas near the Fukushima Daiichi NPS and the enormous expenditures to protect them against a hypothetical risk of cancer. The basis for the precautionary measures is shown to be invalid; the radiation level chosen for evacuation is not conservative. The actions caused unnecessary fear and suffering. An appropriate level for evacuation is recommended. Radical changes to the ICRP recommendations are long overdue.

It is very upsetting to read about the on-going fear and hardship suffered by the more than 90,000 residents, who were evacuated from areas surrounding the Fukushima Daiichi Nuclear Power Station (NPS) in Japan, and the enormous economic penalty, including the $55 billion increase in the cost of fossil fuel imports in 2011, due to the shutdown of almost all of the other NPSs (WNA 2012). As of December 1, more than 230,000 people have been screened with radiation meters (IAEA 2011). The "deliberate evacuation area" was based on a projected radiation dose of 20 milliSievert (mSv) per year (METI 2011a, IAEA 2012). The goal aims to keep additional radiation exposure below 1 mSv annually, particularly for children (METI 2011a, 2011b). And a plan for assistance to the residents affected has been developed (METI 2011b).

Japan is complying with international radiation protection recommendations that are based on the International Commission on Radiological Protection (ICRP) policy of maintaining exposure to nuclear radiation as low as reasonably achievable (ALARA). However, the very precautionary measures are highly inappropriate.

As described by Edward Calabrese (2009), the International Committee on X-Ray and Radium Protection was established by the Second International Congress of Radiology in 1928 to advise physicians on radiation safety measures, within a non-regulatory framework. Radiation protection was based on the "tolerance dose" (permissible dose) concept. The initial level was 0.2 roentgen[1] (R) per day in 1931, based on applying a factor of 1/100 to the commonly accepted average erythema dose of 600 R, to be spread over one month (30 days).[2] It was used as a means to determine the amount of lead shielding needed. Any harm that might occur from exposures below the tolerance level was acceptable. However, geneticists strongly believed the theory that the number of genetic mutations is linearly proportional to radiation dose, that mutagenic damage was cumulative and that it was harmful. They argued that there was no safe dose for radiation; safety had to be weighed against the cost to achieve it.

To avoid adverse effects, early medical practitioners began to control their exposures to x-rays. For example, the British X-ray and Radium Protection Committee was formed in 1921. A study of those who joined a British radiological society revealed a significant health benefit (Smith and Doll 1981). Table 1 shows the ratio of observed/expected numbers of deaths of pre-1921 radiologists (in social class 1) and the ratio of post-1920 radiologists. A reduction from 1.04 to 0.89 is apparent for all causes of death and from 1.44 to 0.79 for cancer deaths. Note that the pre-1921 radiologists had a 44% higher cancer mortality than other men in social class 1, while the post-1920 radiologists had a 21% lower cancer mortality.

After the bombing of Hiroshima and Nagasaki in World War II and the start of the nuclear arms race, geneticists greatly amplified their concerns that exposure to radiation in medical products and atomic bomb fall-out would likely have devastating consequences on the human population's gene pool. Hermann J. Muller was awarded the Nobel Prize in 1946 for his discovery of radiation-induced mutations. In his Nobel Prize Lecture of December 12, he argued that the dose-response for radiation-induced germ cell mutations was linear and that there was "no escape from the conclusion that there is no threshold" (Calabrese 2011c, 2012).

There was great controversy and extensive arguments during the following decade regarding the past human experience, the biological evidence and the strong pressures from Muller and many other influential scientists who migrated from science to politics. The International Committee for Radiation Protection and the national organizations changed their radiation protection policies in the mid-1950s. They rejected the tolerance dose concept and adopted the concept of cancer and genetic risks, kept small compared with other hazards in life. The belief in low-dose linearity for radiation-induced

1 The "equivalent dose" that corresponds to an exposure of 1 R depends on the energy of the x- or γ-radiation and the composition of the irradiated material. For example, if soft tissue is exposed to 1 R of γ-radiation, the dose would be approximately 9.3 mSv (Henriksen and Maillie 2012).

2 In September 1924 at a meeting of the American Roentgen Ray Society, Arthur Mutscheller was the first person to recommend this "tolerance" dose rate for radiation workers, a dose rate that could be tolerated indefinitely (Inkret et al 1995). This level corresponds to 680 mSv/year.

Table 1: Observed and expected numbers of deaths from cancer and all other causes among radiologists who entered the study prior to 1921 or after 1920

Cause of death	Observed (O) and expected (E) numbers of deaths					
	Entry prior to 1921			Entry after 1920		
	O	E	O/E	O	E	O/E
All causes	319	(1) 334.42	0.95	411	541.77	0.76***
		(2) 308.03	1.04		461.14	0.89*
		(3) 327.97	0.97		469.97	0.87**
All neoplasms	62	(1) 49.11	1.26*	72	114.93	0.63***
		(2) 43.07	1.44**		91.07	0.99*
		(3) 35.39	1.75***		68.65	1.05
Other causes	257†	(1) 285.31	0.90*	339†	426.84	0.79***
		(2) 264.96	0.97		370.07	0.92
		(3) 292.58	0.88*		401.31	0.84**

(1) Based on rates for all men in England and Wales.
(2) Based on rates for social class 1.
(3) Based on rates for medical practitioners.
† includes one death with unknown cause.

*P<0.05, **P<0.01, ***P<0.001 } One sided in direction of difference.

mutations was accepted. The acute exposure, high-dose cancer mortality data from the Life Span Study on the Hiroshima-Nagasaki survivors was taken as the basis for predicting the number of excess cancer deaths to be

Table 2: Radiation Exposures of the NPS Workers from 2011 March 11 until December 31

Number of Workers	Radiation Dose (mSv)
135	100 - 150
23	150 - 200
3	200 - 250
6	250 - 678
167	

expected following an exposure to a low dose of radiation or to low level radiation. However, the biology is very different from this picture. Professional ethics require a proper scientific foundation for estimating health risks (Jaworowski 1999, Calabrese 2011a).

Throughout the 20th century, an enormous amount of research has been underway in biology, on genetics and on the effects of radiation on DNA. A very important article, a commentary by Daniel Billen, was published in the Radiation Research Journal (Billen 1990), which is highly relevant to the great concern about the cancer or genetic risk from radiation. Permission was received from Radiation Research to republish it here (appended).

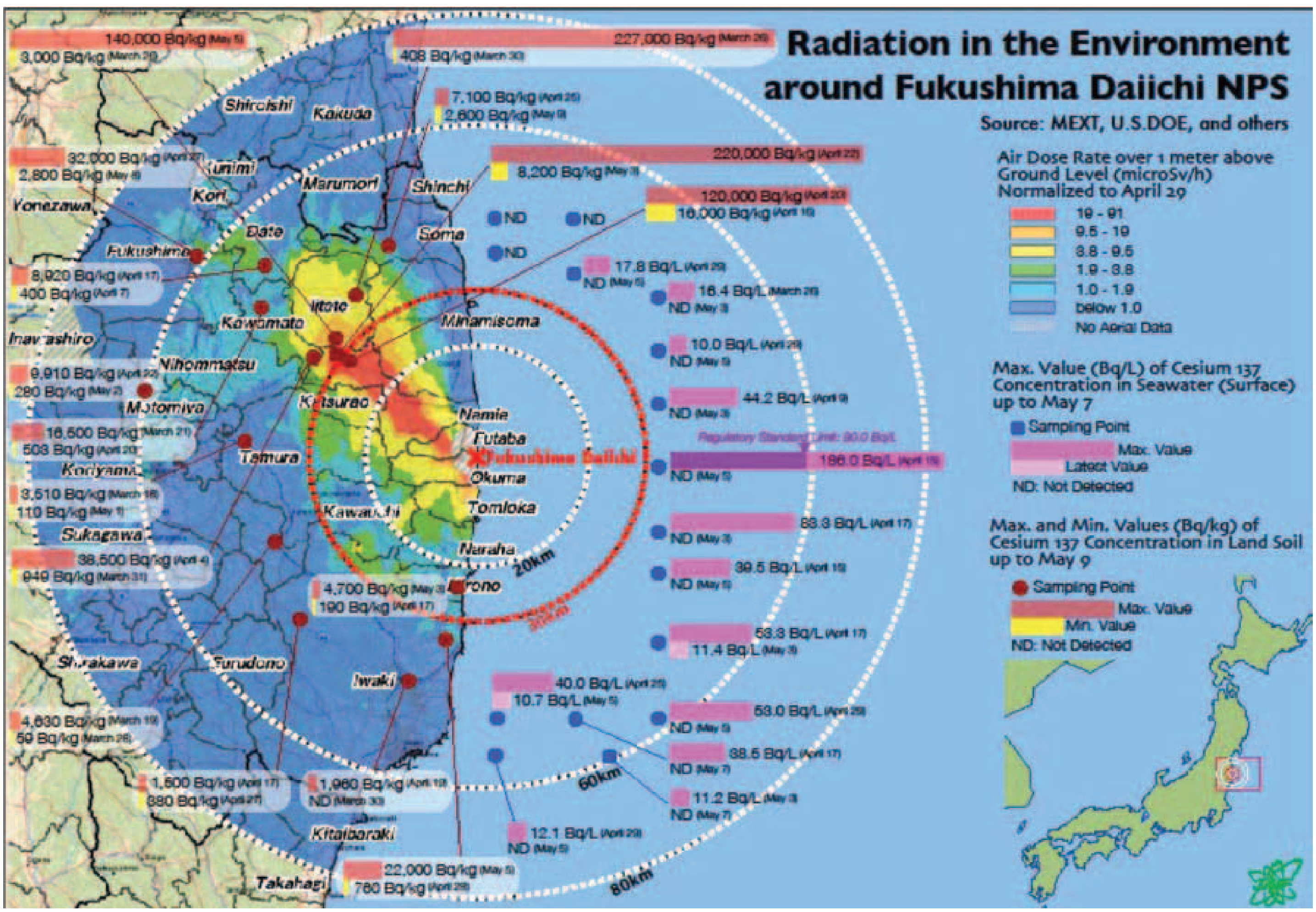


Figure 1: Radiation in the Environment around the Damaged Fukushima Daiichi NPS. (MEXT 2011)

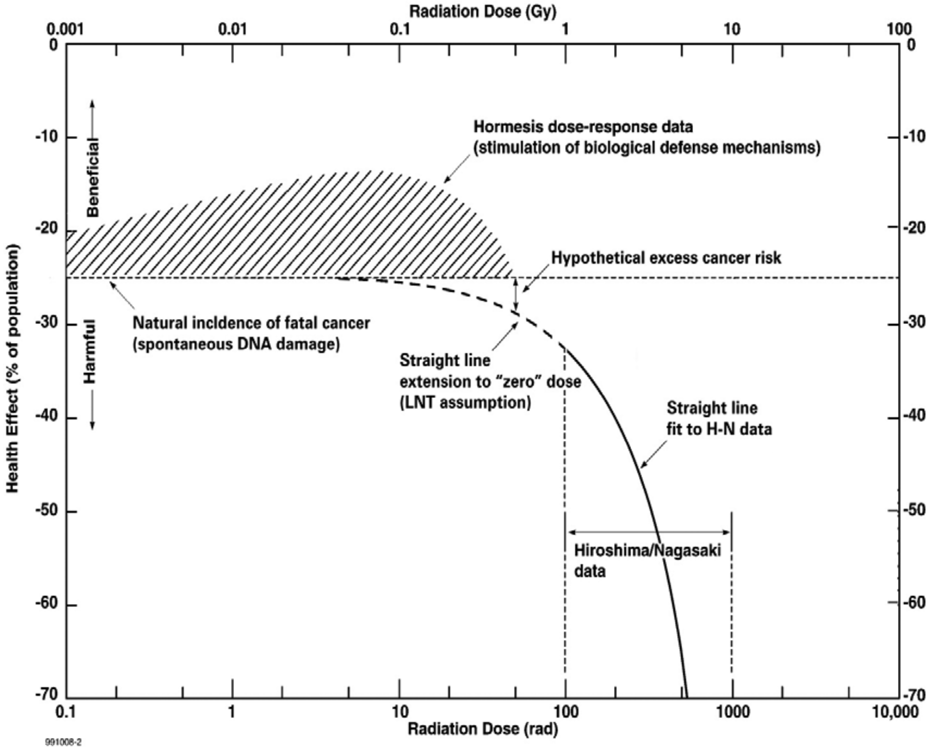


Figure 2: Dose-Response for Short-Duration Radiation Exposure (Cuttler 1999).

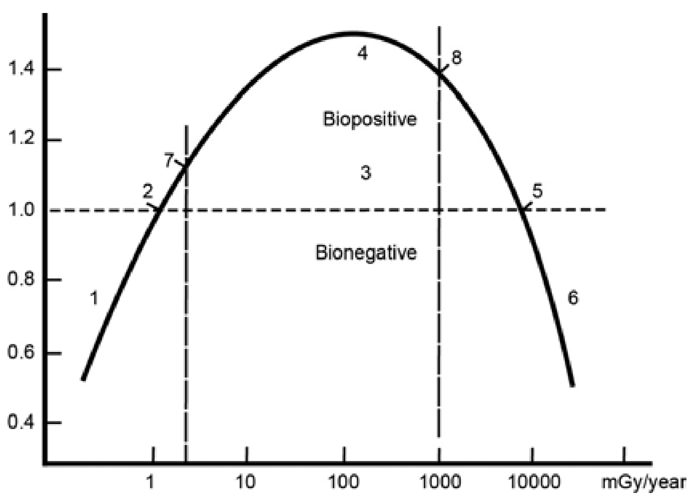


Figure 3: Idealized Dose-Response Curve for Continuous Exposure (Luckey 1991).

1 deficient, 2 ambient, 3 hormetic, 4 optimum, 5 zero equivalent point, 6 harmful, 7 ALARA, 8 AHARS

The Billen article points out that "DNA is not as structurally stable as once thought. On the contrary, there appears to be a natural background of chemical and physical lesions introduced into cellular DNA by thermal as well as oxidative insult. In addition, in the course of evolution, many cells have evolved biochemical mechanisms for repair or bypass of these lesions."

Spontaneous DNA damage occurs at a rate of ~ 2 x 10^5 natural events per cell per day. Compare this with the damage caused by nuclear radiation. The number of DNA damaged sites per cell per cGy is estimated to be 10-100 lesions, 100 to be conservative. A radiation level of 1 mSv delivered evenly over a year would cause on average less than 10 DNA damaging events per cell per year or 0.03 events/cell/day. **This is 6 million times lower than the natural rate of DNA damage that occurs in every person.** And this information has been known for more than 20 years.

The radiation in the environment around the Fukushima Daiichi NPS is shown in Figure 1 (MEXT 2011). It is interesting to note that the radiation received by the plant workers, Table 2 (JAIF 2012), did not exceed the tolerance level specified in 1931 for radiologists.

Recently, Calabrese discovered that Muller had evidence in 1946 that contradicted the linear dose-response model at low radiation levels. Muller did not mention this in his Nobel Prize lecture, suggesting that he still wanted the change in radiation protection policy to proceed, from the tolerance dose concept to a linear-no-threshold risk of cancer and congenital malformations (Calabrese 2011b, 2011c, 2012).

How can ICRP recommendations still be based on protecting against genetic risk at this level, when human suffering and economic costs are so great? The ICRP has been progressively tightening its recommendations for occupational and public exposures, from 50 and 5 mSv/year (ICRP 1958) to 20 and 1 mSv/year (ICRP 1991). Instead of ALARA, the radiation level for evacuation should be "as high as reasonably safe," AHARS (Allison 2009, 2011). For nuclear accidents, the 20 mSv/y level could be raised 50 times higher to 1000 mSv/y, which is similar to the natural radiation levels in many places (Jaworowski 2011). And when low-dose/level radiation stimulation of the biological defences against cell damage and cancer is considered (Luckey 1991, UNSCEAR 1994, Cuttler 1999, Pollycove and Feinendegen 2003, Tubiana et al 2005, Cuttler and Pollycove 2009), Figures 2 and 3, there is no reason to expect any increase in cancer risk. It is very difficult to understand why the ICRP recommendations have not changed accordingly. There would have been no need for this evacuation.

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COMMENTARY

Spontaneous DNA Damage and Its Significance for the "Negligible Dose" Controversy in Radiation Protection

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BILLEN, D. Spontaneous DNA Damage and Its Significance for the "Negligible Dose" Controversy in Radiation Protection. *Radiat. Res.* **124,** 242–245 (1990).

One of the crucial problems in radiation protection is the reality of the negligible dose or *de minimus* concept (*1–4*). This issue of a "practical zero" and its resolution is central to our understanding of the controversy concerning the existence of a "safe" dose in radiological health. However, for very low levels of environmental mutagens and carcinogens including low doses of low-LET radiations (less than 1 cGy or 1 rad), spontaneous or endogenous DNA damage may have an increasing impact on the biological consequences of the induced cellular response. It is this issue that is addressed in this communication.

The following discussion is intentionally limited to a comparison of low-LET radiation since its effects are due primarily to indirect damage in cellular DNA brought about by OH radicals. Indirect effects of low-LET radiation under aerobic conditions are reported to account for 50–85% of measured radiation damage in cells (*5, 6*). High-LET radiation, on the other hand, produces unique DNA damage (*7*) primarily by direct effects (*5*) which is less likely to be properly repaired (*7*).

Spontaneous or intrinsic modification of cellular DNA is ubiquitous in nature and likely to be a major cause of background mutations (*8*), cancer (*9*), and other diseases (*10*). The documentation of this intrinsic DNA decay has increased at a rapid pace in recent years and has not gone unnoticed by contemporary radiobiologists. Setlow (*11*) and more recently Saul and Ames (*12*) summarized the findings of Lindahl and Karlstrom (*13*) and others (*14*) which suggest that approximately 10,000 measurable DNA modification events occur per hour in each mammalian cell due to intrinsic causes.

The current radiation literature will be interpreted to show that ~100 (or fewer) measurable DNA alterations occur per centigray of low-LET radiation per mammalian cell. Therefore every *hour* human and other mammalian cells undergo at least 50–100 times as much spontaneous or natural DNA damage as would result from exposure to 1 cGy of ionizing radiation. Since background radiation is usually less than 100–200 mrem (1–2 mSv)/y, it can be concluded, as discussed by Muller and Mott-Smith (*15*), that spontaneous DNA damage is due primarily to causes other than background radiation.

"INTRINSIC" OR "SPONTANEOUS" DNA DAMAGE

DNA is not as structurally stable as once thought. On the contrary, there appears to be a natural background of chemical and physical lesions introduced into cellular DNA by thermal as well as oxidative insult. In addition, in the course of evolution, many cells have evolved biochemical mechanisms for repair or bypass of these lesions.

Some of the more common "natural" DNA changes include depurination, depyrimidination, deamination, single-strand breaks (SSBs), double-strand breaks (DSBs), base modification, and protein–DNA crosslinks. These are caused by thermodynamic decay processes as well as reactive molecules formed by metabolic processes leading to free radicals such as OH, peroxides, and reactive oxygen species.

Shapiro (*14*) has recently discussed and summarized the frequency at which various kinds of spontaneous DNA damage occur. Spontaneous DNA damage events per cell per hour are shown in Table I and were estimated from the data presented by Shapiro [Table II (*14*)].

For single-stranded DNA of mammalian cells at least 8×10^3 damage events occur/cell/h, whereas for double-stranded DNA there were $\sim 6 \times 10^3$ damage events per hour (Table I). While the ratio of single-stranded DNA to

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TABLE I
Estimated Spontaneous DNA Degradation Events (Cell/h)[a]

Reaction	Single-strand DNA	Double-strand DNA
Depurination	4000	1000
Depyrimidination	200	50
Deamination of cytosine	4000	15
Chain break resulting from depurination	—	1000
Direct chain break	—	4000

[a] Calculated from Shapiro (*14*).

double-stranded DNA varies with phase of the cell cycle, it is reasonable to assume that double-stranded DNA is the usual configuration for most cellular DNA at any one time. From the data summarized in Table I it is not unreasonable to suggest that, at a minimum, the spontaneous DNA damage is of the order of 6–10 $\times$ 10^3 events/cell/h and to use 8 $\times$ 10^3 DNA damage events/cell/h as a reasonable average for the purpose of discussion. This allows a calculation of 1.9 $\times$ 10^5 spontaneous cellular DNA damaging events/cell/day or 7 $\times$ 10^7 per year in mammals including humans (Table II). The lifetime load of spontaneous DNA damage events per cell is then $\sim$5 $\times$ 10^9 if an average life span of 75 years is allowed for humans.

DNA DAMAGE INDUCED BY IRRADIATION

Several recent reviews summarize the types and quantities of alteration of DNA in cells caused by exposure to low-LET radiation (*16–18*). The reader should refer to these for references to the original works from which the reviews were drawn.

The estimate of about 100 DNA events/cell/cGy used in this discussion is based on information contained in the reviews by Ward (*16, 20*) and assumes the molecular weight of the mammalian genomic DNA to be 6 $\times$ 10^{12} Da, constituting about 1% of the cell weight.

Ward [Table II (*16*)] lists the amount of energy deposited in various DNA constituents/cell/Gy. From this table a total of 13.3 DNA events/cGy is calculated. His estimate of damaged DNA sites/cell/cGy is 10–100. I chose the 100-lesion estimate to make as reasonable a conservative comparison with spontaneous DNA damage as possible (Table II). This number of damaged sites would include both direct and indirect DNA damage.

SPONTANEOUS VS INDUCED DNA MODIFICATIONS AND THEIR BIOLOGICAL CONSEQUENCES

Wallace has recently reviewed the nature of the DNA lesions caused by active oxidizing species produced both naturally and by low-LET radiation (*17*). Oxidizing radicals and especially OH radicals resulting from either cause produce similar types of DNA lesions (*17–19*). The enzymes involved in their repair are similar whether the DNA damage is produced spontaneously or by radiation. However, radiation is known to induce an error-prone repair system in bacterial cells and perhaps in mammalian cells as well (*21, 22*).

DNA glycosylases and endonucleases are involved in the repair of base damage. Other nucleases are available for sugar damage repair (*17*). Recognition of the damage site by the appropriate enzymes is dependent not on the initiating event but on the chemical nature of the end product. These end products appear to be similar whether induced by natural causes or radiation (*17*). It would seem reasonable to conclude that, due to common oxidizing radicals, many of the qualitative changes in DNA are quite similar for radiation-induced or spontaneous DNA damage.

TABLE II
DNA Damage Events per Mammalian Cell

Character of event	Spontaneous DNA damage events			DNA damage/cGy[a]
	Per second	Per hour	Per year	
Single-strand breaks	1.4	$\sim$5 $\times$ 10^3	$\sim$4.4 $\times$ 10^7	10
Double-strand breaks				0.4
Depurination and/or		$\sim$1.5 $\times$ 10^3	$\sim$1.4 $\times$ 10^7	
base lesions	0.8	$\sim$1.25 $\times$ 10^3	$\sim$1.1 $\times$ 10^7	9.5
Total events	2.2	$\sim$8.0 $\times$ 10^3	$\sim$7 $\times$ 10^7	$\sim$20
cGy equivalents (1 cGy = 100 events)[b]	0.022	8.0 $\times$ 10^1	7 $\times$ 10^5	

[a] From Ward (*20*).
[b] Since other radiation-induced DNA damage such as DNA–protein crosslinking and base modifications (*18*) occur, 100 events/cGy is used as a "ballpark" value for ease of comparison with spontaneous events.

The quantity and distribution of each class of lesion may, however, differ significantly. As indicated earlier there would appear to be relatively more DNA strand breaks than other lesions resulting from spontaneous causes as compared to radiation insult. A good portion of these may result from depurination (Table I) with production of 3′ OH termini ("clean ends") as part of the repair process.

Many of the DNA strand breaks caused by low-LET radiation are incapable of serving as primer for DNA polymerase (*23*). However, endo- and exonucleases exist which can restore these blocking ends to clean ends and allow completion of the repair process (*17*).

A strong correlation exists between DNA DSBs and lethality in mammalian cells for low-LET radiation. While the quantity of DSBs produced by ionizing radiation is fairly well documented, this is not true for spontaneous DSB production in mammalian cells.

In spontaneous DNA decay, formation of a DSB is likely to be the result of single-strand events occurring in close proximity on each daughter strand and leading to cohesive ends which can be repaired easily by a ligation step.

A survey of the literature on the doubling dose for mutagenesis in eukaryotes exposed to low-LET radiation indicates a range of 4 to 300 cGy and for carcinogenesis a range of 100 to 400 cGy. Using the "ballpark" value of approximately 100 DNA events/cell/cGy, this would represent a range of 400 to 40,000 induced DNA damage events per doubling dose. Using 100 cGy as the approximate doubling dose, a total of 1×10^4 DNA damage events would be required to induce mutations in numbers equal to that observed in nature. This is approximately the number of DNA events (8.0×10^3) produced spontaneously in each cell/h (Table II).

THE NEGLIGIBLE DOSE CONTROVERSY

The comparison of low-LET radiation-induced DNA damage with that which occurs spontaneously indicates (Table II) that a relatively large number of DNA damage events can occur spontaneously during the lifetime of mammalian and other cells.

Dose protraction over a period of weeks or months would lead to an increasing ratio of spontaneous DNA damage events to those caused by irradiation. By extrapolation from high doses and high dose rate as discussed by Ward (*16, 20*), 1 cGy delivered in 1 s would cause 40–50 times as many DNA damaging events per cell as that caused spontaneously during the same time span (Table II). However, 1 cGy delivered evenly over 1 year would cause (on average) less than 1 DNA damaging event per cell/day. This can be compared to $\sim 2 \times 10^5$ natural events caused per cell/day.

From these numbers, it seems reasonable to suggest that there does exist a "negligible" dose in the range of our terrestrial background annual radiation dose of ~1 mSv (~10 DNA events/cell/year). This can be compared to the approximately 7×10^7 DNA events/cell/years produced by spontaneous causes.

Adler and Weinberg (*24*) have proposed that the standard deviation of the background irradiation (~0.2 mSv) be used as an acceptable additional dose due to human activities. This would lead to ~2 additional induced DNA damaging events/cell/year as compared to $\sim 7 \times 10^7$ spontaneous DNA damage events. Considering the magnitude of the spontaneously induced DNA changes in each human cell, it is not unreasonable to predict that 0.2 mSv delivered over a year would have negligible biological consequences.

When temporal considerations are factored in, it becomes clear that spontaneous DNA damage in mammalian cells may be many orders of magnitude greater than that caused by low and protracted radiation doses, especially in the terrestrial background range of 1–2 mSv (100–200 mrem) per year. It is important that further studies on the effects of both ionizing radiations and spontaneous events on DNA decay and repair be conducted to better understand the practical health consequences of low and protracted doses of radiation (*2, 9, 25*).

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Opinion

Failure to condemn wind may condemn Darlington B

By DON JONES

*[**Ed. Note:** Don is a CNS member and frequent contributor to the CNS Bulletin.]*

Unless sense prevails, by 2015 the Ontario power grid is going have around 8,000 nameplate MW of wind, solar and bioenergy, mostly wind, and 10,700 MW by 2018. Even today with just over 1,700 MW of wind the grid is unmanageable during periods of surplus baseload generation (SBG) without exporting large amounts of electricity at ridiculously low prices, even negative (reference 1), or powering down or shutting down nuclear plants (reference 2). The Independent Electricity System Operator (IESO) has finally proposed new rules (SE-91 on Renewable Integration) to integrate wind into the grid. Rather than power manoeuvre or shutdown nuclear and baseload hydroelectric units during SBG periods it wants to dispatch wind off the grid first. The present approach, at least for those wind generators with feed-in-tariff contracts, relies on market incentives, like negative pricing and payment for foregone energy, to reduce output during SBG periods.

The proposed new IESO rules will mean paying all the wind generators for the foregone energy (energy that did not get onto the grid), calculated using data from the proposed centralized forecasting system that consumers, not the wind generators, will be paying for. Dispatching wind every five minutes during SBG events (usually overnight and weekends) can give a better match of baseload supply to demand than the present coarse manoeuvring, or even shutdown, of Bruce B nuclear units that prefer to drop 300 MW rather than smaller, say 80 MW, increments (reference 3). Dispatching wind and hydro ahead of nuclear will reduce the amount of SBG that has to handled by Bruce B units using a steam bypass system that was not originally designed for the task. The IESO has not promoted improvements to steam bypass systems although it is prepared to use its existing capability where and when available.

The Ontario Society of Professional Engineers (OSPE) has issued a draft report (reference 4) on the integration of wind into the grid that views nuclear as a «transition fuel» to buy time for affordable renewables and makes a case for improving the robustness of the steam bypass systems on the nuclear units so that they can be powered down during SBG events without dispatching wind off. Since there is expected to be around 7,000 nameplate MW of wind on the grid by 2015, or earlier, it is doubtful if the steam bypass improvements could be done in time anyway even if they could be done during unit outages instead of during the refurbishments. Nevertheless steam bypass improvements have to be made (reference 6) but not for the reason given by OSPE.

Unfortunately, rather than condemning wind on the grid the IESO and the OSPE (and others, who should know better) assume that wind is here to stay and are prepared to support it and in the case of OSPE even going so far as manoeuvring nuclear units for its accommodation. With no change in the nuclear scene this means that natural-gas fired generation and hydroelectric generation will continue to provide for the intermediate and peak loads with gas also providing flexible support for wind. In the short term even the lost generation from the retirement of Pickering can be replaced by two or three large combined cycle gas turbine units which would provide flexible power to support more wind when the Ontario demand picks up, and remove the need for Darlington B.

The government›s rationale for wind was that it was replacing coal and would reduce greenhouse gas emissions whereas in fact it is gas that is replacing coal with wind now, supposedly, reducing the emissions from the gas-fired plants. Any reduction in greenhouse gas emissions would be slight to non-existent (reference 5) and at high cost. Life cycle greenhouse gas emissions from shale gas are said to be comparable to coal. Without the completely superfluous wind, which is more of a hindrance than a help, the camouflage is removed and the substitution of gas for coal becomes obvious. However gas has no long term future (which means wind has no long term future) because of emissions and future cost concerns. Inevitably the focus has to change from gas to flexible nuclear.

The work to get Ontario to a clean nuclear and hydro power grid without gas has to start now. By 2024, or thereabouts, all refurbishment work and any new Darlington B construction will have been completed and a skilled nuclear workforce will be looking for work. The refurbished nuclear units will be decommissioned around 2045/2050 and likely replaced by new nuclear because of the uncertainty of gas. However the nuclear workforce will have long gone.

The solution is to put a continuous new build program into affect after 2024. This can only happen if the refurbished Bruce and Darlington units have improved load cycling/following capability such as a more robust steam bypass system so that they can be powered down during the overnight and weekend periods of SBG caused by the new build nuclear units. If any of the several thousands of proposed wind turbines are still operating by then they can be dispatched off to minimize the manoeuvring of the nuclear units. This load cycling would allow more new nuclear, potentially around 6,000 MW in addition to the 2,000 MW of Darlington B, to be added to the grid to replace an equal amount of the expensive greenhouse gas emitting gas-fired generation (reference 6) that is replacing coal. For all this to happen means the power manoeuvring capability of the present nuclear units has to be improved during the refurbishments (or normal outages if it can be done), using steam bypass with or without changes to the way the reactor is operated. There really is no time to waste.

*[**Ed. Note:** An earlier version of this article can be seen on Steve Aplin›s website]*

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The Canadian Experience with Fukushima: Response to an Off-Shore Nuclear Emergency

by T.J. JAMIESON[1], R. JAMMAL[1], G. RZENTKOWSKI[1]

[Ed. Note: This is an extended abstract of the Presentation to the 26th Biannual Conference of the Nuclear Societies in Israel, Meridien Hotel, Dead Sea, February 21, 2012. Terry Jamieson is a CNS member and Vice President of the Technical Support Branch of the CNSC.]

Introduction

In this paper we discuss Canada's response to the March 2011 events at Fukushima, from a nuclear regulatory point of view, including emergency management. We will also describe the actions taken by the Government of Canada and the challenges with obtaining timely and complete information. Finally, three specific actions taken by the CNSC, namely the establishment of a Fukushima Task Force, the creation of an External Advisory Committee and the results of an IAEA review of the Canadian Nuclear Safety Commission (CNSC) response to the events at Fukushima are summarized.

Nuclear Emergency Response In Canada

The management of a nuclear emergency in Canada involves overlapping municipal, provincial and federal jurisdictions:

- Onsite preparedness and response is the responsibility of the nuclear power plant (NPP) licensee
- Offsite preparedness and response is the responsibility of the province, in coordination with municipalities, where the NPP is located
- At the request of the province, the Government of Canada will provide support to the province via the resources of multiple federal agencies
- The CNSC continues to have regulatory oversight of the licensee during an emergency

Off-Shore Versus Domestic Nuclear Emergencies

The primary goals of nuclear emergency management for off-shore nuclear emergencies differ somewhat from the objectives during the management of a domestic nuclear emergency. During the Fukushima events, the primary objectives were:

- Protection of Canadians in Japan
- Protection of Canadians in Canada
- Protection of the Canadian environment
- Evaluating any immediate implications for the Canadian reactor fleet

Actions Taken By The CNSC

While major accidents such as this happen very infrequently, it is vitally important that all nuclear facility designers and operators, nuclear regulators, and emergency response organizations learn every possible lesson. Recognizing the severity of the accident and the need for the national regulatory authority to lead, monitor, advise and communicate with both the public, decision-makers and other stakeholders, the CNSC responded immediately to the accident at Fukushima Daiichi with the following actions:

- Activated its Emergency Operations Centre in Ottawa and staffed it 24/7 to monitor the emergency, assess early reports and provide timely, accurate information to Canadians and to other Canadian government departments and agencies
- Requested licensees of Canadian Class I nuclear facilities1, under section 12(2) of the *General Nuclear Safety and Control Regulations*, to review the lessons learned from the Fukushima Daiichi accident
- Performed inspections of all NPPs and other nuclear facilities in Canada to assess the readiness of mitigating systems – these inspections covered seismic preparedness, firefighting capability, backup power sources, hydrogen mitigation and irradiated fuel bay cooling
- Established a Task Force to evaluate the operational, technical and regulatory implications of the accident and the adequacy of emergency preparedness for NPPs
- To aid the Canadian response and advise Canadian citizens in Japan, the CNSC performed source-term calculations and enhanced its public communications, which included daily information updates
- Participated in inter-governmental discussions at all levels
- On the national level, Canada conducted ongoing radiation monitoring across all of its territory and deployed experts to the IAEA
- On the international level, Canada worked closely with other national nuclear regulators (including the United States, the United Kingdom, and France) to share and to validate information.

In addition, the CNSC commissioned an External

1 Canadian Nuclear Safety Commission, Ottawa, Canada

Advisory Committee to assess the regulatory response and the CNSC was the first nation to request a Fukushima module as part of an International Atomic Energy Agency (IAEA) Integrated Regulatory Review Service (IRRS) mission.

Communications

Fukushima presented some particular information challenges, specifically in getting information early in the event so that modeling assumptions could be verified. There were conflicting reports from media, international agencies and from various sources in Japan. Also, there were challenges in getting information processed, verified and approved so that public communications could be made.

And finally, it is worth noting that Fukushima was the first major nuclear accident to occur during "the internet age". The speed at which information, and in some cases misinformation, was posted to the internet greatly increased the demands on emergency management and communications staff as they attempted to review and either confirm or refute the information.

Fukushima Task Force[1]

The CNSC Fukushima Task Force was created with the objective of reviewing the capability of NPPs in Canada to withstand conditions similar to those that triggered the Fukushima accident. Specifically, the CNSC Task Force examined the response of NPPs to external events of higher magnitude than have previously been considered. It also examined the licensees' capability to respond to such events. The focus was on the need to "anticipate the unexpected": events such as earthquakes, tornadoes or hurricanes that may cause a prolonged loss of electrical power, resulting in operators not being able to continue cooling the reactors. The focus was also on the need for an integrated response capability.

In the process of formulating the safety review criteria, the CNSC Task Force considered all the applicable lessons learned to date from the Fukushima accident and reviewed selected international reports to ensure that all aspects relevant to Canada were addressed. Effectively, the CNSC Task Force has subjected the Canadian NPPs, the existing emergency response measures, and the regulatory framework and supporting processes to a systematic and comprehensive "stress test" to evaluate means to further protect the health and safety of Canadians and the environment. The post-Fukushima review has examined events more severe than those that have historically been regarded as credible and their impact on the NPPs. The CNSC Task Force has proposed changes to designs or procedures, wherever gaps were found, in order to minimize or eliminate their impact. Specifically, the CNSC Task Force made recommendations for:

- Strengthening reactor defence in depth
- Enhancing emergency response
- Improving regulatory framework and licensing

Overall, the CNSC Task Force concluded that Canadian NPPs are safe and that the risk posed to the health and safety of Canadians or to the environment is small. The CNSC staff has also verified that all Canadian NPPs are located far from tectonic plate boundaries and that the threat of a major earthquake at a Canadian NPP is negligible.

The CNSC Task Force is confident that the improvements recommended will further enhance the safety of nuclear power in Canada and will reduce the associated risk to as low as reasonably practicable.

Under the oversight of the CNSC and its staff, Canadian NPPs have been operating safely for over 40 years. As has always been the case, they will only be licensed if the CNSC is satisfied that they will continue to be operated safely.

External Advisory Committee[2]

The Canadian Nuclear Safety Commission (CNSC) also established an external advisory committee to assess the organization's processes and responses in light of the lessons learned from the Fukushima nuclear incident, which has highlighted the importance of nuclear safety around the world.

Committee members reviewed the CNSC's processes including the immediate response to the Fukushima incident, its connections with the rest of government and international organizations and its interactions with the Canadian nuclear sector and its regulated industries. They also reviewed the CNSC's communications with affected stakeholders, including governments, other nuclear regulators, and the public. Finally the committee assessed the implications on the CNSC's regulatory approaches resulting from the international response to Fukushima, such as international stress tests and the International Atomic Energy Agency action plan.

IRRS Fukushima Review[3]

The IRRS Fukushima review was completed in December 2011. The review found strength in the CNSC response; our response was found to be prompt, robust and comprehensive.

A good practice was identified: CNSC completed a systematic and thorough review of the lessons learned from the accident, making full use of all the available information including the review of actions taken by other international regulators. The CNSC was found to have set up an action plan for addressing all the finding and recommendations of the Fukushima Task Force.

Two recommendations and a suggestion were offered.

It was recommended that a national assessment of off-site emergency plans be undertaken, and that periodic full scale exercises are re-instituted (the last one having occurred in 2007). A suggestion was offered that a peer review of the Canadian nuclear emergency preparedness and response be undertaken. All three of these findings were directed at the Government of Canada, as opposed to the CNSC.

Conclusions

The events at Fukushima have led all international regulators and licensees to review their readiness for external events. While no major changes to the Canadian nuclear regulatory system have been identified, the various findings from the CNSC Fukushima Task Force, along with the recommendations of the External Advisory Committee and the IRRS Mission are being reviewed and incorporated into the ongoing CNSC regulatory improvements program.

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[Ed. Note: Terry Jamieson's full presentation is available at http://www.nuclearsafety.gc.ca/eng/pdfs/Presentations/VP/2012/February-21-2012-Terry-Jamieson-Presentation-Conference-of-the-Nuclear-Societies_e.pdf]

Operational Transparency: An Advanced Safeguards Strategy For Future On-Load Refuelled Reactors

by J.J. WHITLOCK[1] and D. TRASK[1]

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Abstract

The IAEA's system for tracking fuel movement in an on-load refuelled heavy-water reactor is robust, but an opportunity remains to exploit the wealth of data streaming from the reactor vault during operation and provide real-time, third-party monitoring of reactor status and history. This concept of Operational Transparency would require that large amounts of operational data be reduced in near-real time to a small subset of high-level information. Operational Transparency would enhance the IAEA's ability to monitor the state of the core to an unprecedented level. This paper provides an overview of the novel concept of Operational Transparency in heavy water reactors, using potential application to CANDU reactors as an example, and explores some of the technical challenges that will need to be solved for efficient implementation.

1. Introduction

Traditional "comprehensive" IAEA safeguards (i.e. those implemented under a State-level Comprehensive Safeguards Agreement, or CSA [1]) are based upon accountancy and control of nuclear material, administered through a "State System for Accounting for and Control of Nuclear Material" (SSAC – in Canada represented by the CNSC) on behalf of the IAEA, and verified by the IAEA through inspection. The IAEA maintains Continuity of Knowledge (CoK) between inspections through a combination of Containment and Surveillance (C&S), including seals, cameras, and other monitoring instrumentation. In addition, the IAEA has access to operational data from the safeguarded facilities, which it can use in the investigation of perceived anomalies.

Many countries, including Canada, have also implemented an Additional Protocol to these comprehensive safeguards[2], giving the IAEA enhanced inspection and sampling powers that enable it to draw broader conclusions about a State's likelihood to be engaged in clandestine proliferation activities, particularly

1 Atomic Energy of Canada Limited

2 See www.iaea.org/OurWork/SV/Safeguards/sg_protocol.html.

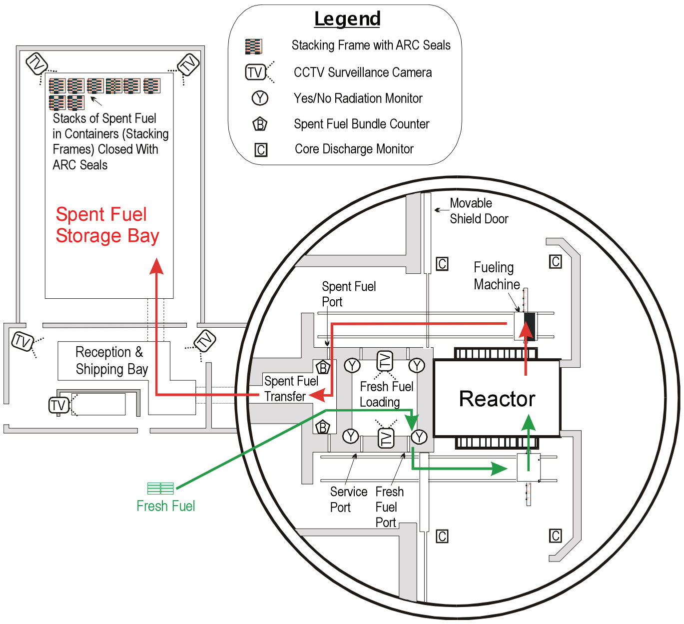

Figure 1: Typical IAEA Safeguards Equipment for CANDU [4]

at locations beyond the boundaries of facility-based traditional safeguards. The Additional Protocol was developed in response to inherent weaknesses in the traditional approach exposed by Iraq's clandestine program following the first Gulf War (1990-'91).

A smaller number of countries, including Canada [2], operate under an Integrated Safeguards (IS) regime, based upon the above State-level conclusion about absence of proliferation activity. Under an IS regime safeguards verification can be less frequent, and randomly scheduled, allowing greater efficiency for the IAEA. The IS regime relies on a more "information driven" approach to verification; in effect the IAEA endeavours to work "smarter" rather than "harder" to achieve the same overall safeguards goals.

Globally, the class of on-load refuelled (OLR) reactors is represented most prominently by the CANDU design. CANDU reactors in Canada and off-shore, whether or not operating under an IS regime, are subject to safeguards that include special instrumentation to count fuel bundles exiting the core and entering the spent fuel reception bay (see Figure 1). In this respect, CANDU reactors tend to have more advanced and comprehensive safeguards than other commercial designs [3]. For example, the safeguards approach to a PWR relies on the fact that unauthorized access to the core between refuelling outages would be obvious to outside observers due to the required shutting down of the core.

2. The Challenge

The IAEA considers CANDU reactors to be sufficiently safeguarded, but at a greater expense to the IAEA than other designs due to the need to verify daily fuel movement and more frequent transfers of used fuel to dry storage. Significant efficiencies have been achieved in both of these areas, particularly in jurisdictions operating under an Integrated Safeguards regime, through remote monitoring and reduced inspection frequency [2]. Additional achievements in efficiency in the safeguarding of CANDU reactors will of course always be welcomed.

More generally however, some concern is associated with the safeguardability of advanced (non-CANDU) OLRs now under development – including both process flow reactors (aqueous or slurry systems such as the Molten-Salt Reactor), and "quasi-process" flow reactors such as the pebble-bed designs. These technologies require a stochastic approach to fuel management that is fundamentally unsuited to traditional IAEA nuclear material accountancy and control methods. This has prompted the IAEA Novel Technologies Unit, for example, to explore more advanced and less discrete methods of monitoring, such as the potential use of anti-neutrino detectors to monitor bulk consumption of fissile material.

At a somewhat higher level of observation is the following notion: regardless of the technical soundness of traditional safeguards processes, there will likely be an need within the "nuclear renaissance" to provide increasing levels of assurance and comfort to the public that safeguards are robust, in order to retain social acceptance for continued and expanded operation. In a similar sense that guides emerging nuclear safety and security concepts, one envisages a need for increased transparency of the soundness of nuclear safeguards. The more linked these goals are to inherent and operations-based features of the technology, the more confidence the public will tend to have in their effectiveness.

It is in this context of increased efficiency and effectiveness with regards to emerging OLR safeguards implementation, as well as social acceptance of nuclear safeguards in an evolving nuclear renaissance, that the concept of "Operational Transparency" is proposed as an attractive, and perhaps necessary, safeguards concept for further development, with specific application to current heavy water reactors for development and demonstration purposes, as outlined below.

3. The Opportunity

CANDU reactors represent conceptually a "stepping stone" in the technology path from current bulk-refuelled systems with discrete accountancy, to process-flow OLRs with stochastic accountancy. A CANDU system is a well-characterized, well-understood system with a long track record of robust safeguards, while at the same time involving a daily flow of a relatively small-item fuel inventory during operation.

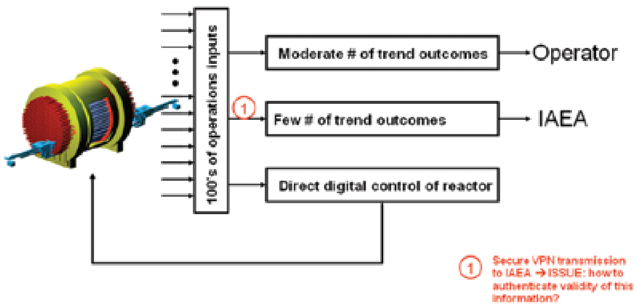

Figure 2: Concept of Operational Transparency applied to CANDU

It is conceivable that CANDU reactors could be utilized in the development of advanced safeguards techniques that fall under the general category of "Operational Transparency" – the use of real-time operational data in the implementation of safeguards monitoring. Currently, spent fuel reprocessing plants represent the biggest challenge to the IAEA in terms of process-flow accountancy, although most of these facilities have historically avoided full IAEA safeguards since they tend to be located within Nuclear Weapons States. As the IAEA makes increased use of remote monitoring of discrete and process-flow systems, it becomes a smaller and smaller additional step to remotely monitor the actual operational data of these systems, in real time.

The advantage of implementing this approach on a demonstration basis at a CANDU plant is that the data characterizing fuel movement already exists, since fuelling machine movement within the vault is an automated and fully indexed process. In combination with the wealth of in-core data available from operational instrumentation, this presents a sizable real-time digital record characterizing the use and movement of fissile material, which the IAEA can mine for trend verification. The challenges, therefore, lie in the authentication of the raw data itself, and the efficient processing and reporting of information.

These two challenges are briefly addressed below.

4. CANDU Operational Transparency

As mentioned above, the IAEA currently has access to operational data from CANDU stations; however, in practice this wealth of information is only mined in the case of anomalies. The goal of Operational Transparency is to access much the same information, but in real time or near-real time through the same process and status signals used by the plant Operations. In the case of a CANDU reactor this would include in-core flux measurements, pressures, temperatures, reactivity mechanism positions, and fuelling machine positioning. This large amount of data would be processed by IAEA software that determines operational trends and flags deviations from routine operation.

The emphasis, therefore, is on trending and stochastic analysis of data, rather than discrete accountancy. This approach is in alignment with the mode of operation of process-flow facilities, and also in alignment with the emerging concept of "Information-Driven Safeguards" that the IAEA is moving towards as an efficiency measure.

This information flow is shown in Figure 2, starting with hundreds of operational inputs from the reactor core. These signals are used in the direct digital control of the reactor. The same raw signal flow is processed to provide trending and other status updates to the Operator, representing a moderate number of outputs that can be selected, displayed and further analysed in the control room or by Operations support staff elsewhere at the site.

The innovation of Operational Transparency is to independently process this same raw signal flow, either on IAEA servers at the plant site or remotely at IAEA headquarters in Vienna, and produce a relatively small number of trended outcomes that inform IAEA safeguards verification staff. For example, one can think of a number of output flags numbering less than ten, of which any single negative output indicates a significant deviation from normal operation based on processing and trending of hundreds of raw inputs.

The software to provide this trending and analysis is essentially similar to that which is used by Operations at the plant itself. The challenge, therefore, is not necessarily the processing of the data to provide useful intelligence at the IAEA, but the robustness of the data flow itself as indicated in Figure 2: authentication of the original data (which originates from the reactor Operations instrumentation), and reliability of the data transmission (which originates in the State of potential concern). Robust cyber security is therefore a critical component of Operational Transparency.

5. Achieving a Necessary Level of Cyber Security

The sheer quantity of data logged from any operating nuclear system will require an innovative approach to cyber security in order to establish confidence in the information. Fortunately the voluminous and systemic nature of the data itself will provide some measure of this confidence, in that the interaction of the hundreds of data flows is a complex relationship leading to system-wide signatures that will be difficult to mimic. Trending software can be tuned to look for particular anomalies, and trends of anomalies that will highlight the presence of data tampering.

The strategy is to use the properties of the process itself to verify streams of data to one another.

For example, the detailed flux map of an operating CANDU core, along with zone level indicators, can be used to generate an expected fueling scenario (in a similar process that the Operator would be expected to use to generate fueling scenarios). This expected scenario can then be digitally compared against the actual fueling operation as interpreted from fuelling machine movement and core discharge monitors. Significant discrepancies would be flagged for further investigation, and it is only at this point that human engagement in the verification process takes place.

Another advanced technique of data authentication is to multiplex the raw signal data with a unique signature that corresponds specifically to the raw data source and can be manipulated in real time. The manipulation of the signature and corresponding timestamp ensure that the data originated from that specific source at that specific time and thus ensures that the data was not pre-recorded or spoofed by another source.

In addition to the issue of data authentication at source, a subsequent concern is reliability of the data transmission itself. In this respect the IAEA has a significant amount of experience with Remote Monitoring, and has developed sufficient confidence in the effectiveness and efficiency gains presented by the technology to move towards a broader implementation of the concept of Remote Safeguards Inspections [5] [6] [7]. The ability to remotely collect and analyse both monitoring and operational data is recognized as a mature option that enables the IAEA to reduce costs while implementing many of the effectiveness measures introduced by Integrated Safeguards. Reliability of data transmission therefore does not appear to present a significant challenge to the concept of Operational Transparency, although the sheer increase in volume of data may present an added technical challenge. In this respect it is possible that remote (satellite) data processing at the site, and transmission of a reduced data set to IAEA headquarters, would present one possible solution.

6. Summary

In summary, Operational Transparency offers the following enhancements to the current reactor safeguards regime:

1 Access to the core of an OLR while operating, in a virtual sense. The current paradigm of monitoring material flow in and out of the core is adequate for CANDU technology but will be insufficient for advanced process flow and quasi-process flow reactor technologies.

2 Dependence upon trending and stochastic processes, with a resulting greater ability to detect unforeseen off-normal events. The need to second-guess all modes of technology misuse or material acquisition, required with deterministic safeguards approaches, is replaced with a system-level sensing capability.

3 Significant example of "information-based" safeguards, which can potentially offer more comprehensive coverage, using less IAEA inspector time and resources. Efficient processing of operational information robustly supplied and verified, can therefore enhance a traditional CSA regime or support an Integrated Safeguards implementation.

4 A perception of greater transparency of application, in that independent oversight of nuclear material movement and storage is tied to operational data that is difficult to mask or modify. This leads to increased public confidence in the effectiveness of safeguards based on this concept.

Strategically, prototype application of Operational Transparency to a CANDU plant would provide a testbed for development of stochastic remote monitoring techniques for use with advanced process-flow and quasi-process flow reactor systems under development.

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AECL Passive Autocatalytic Recombiners

by L.B. GARDNER[1] and K. MARCINKOWSKA[1]

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Abstract

Atomic Energy of Canada Limited's (AECL) Passive Autocatalytic Recombiner (PAR) is a passive device used for hydrogen mitigation under post-accident conditions in nuclear reactor containment. The PAR employs a proprietary AECL catalyst which promotes the exothermal reaction between hydrogen and oxygen to form water vapour. The heat of reaction combined with the PAR geometry establishes a convective flow through the recombiner, where ambient hydrogen-rich gas enters the PAR inlet and hot, humid, hydrogen-depleted gas exits the outlet.

AECL's PAR has been extensively qualified for CANDU and light water reactors (LWRs), and has been supplied to France, Finland, Ukraine, South Korea and is currently being deployed in Canadian nuclear power plants.

1. Introduction

Atomic Energy of Canada Limited's (AECL) Passive Autocatalytic Recombiner (PAR) is designed for use in post-accident conditions in which hydrogen is present in reactor containment. The recombiner converts hydrogen and oxygen into water vapour and heat by means of a catalytic reaction. The heat of reaction along with the PAR geometry creates a natural convective flow through the recombiner, eliminating the need for pumps or fans to bring fresh hydrogen to the surface of the catalyst (see Figure 1).

The AECL PAR has undergone extensive qualification testing for design basis accident (DBA) and severe accident (SA) scenarios for CANDU reactors and light water reactors (LWRs). The qualification testing was performed in the Large-Scale Vented Combustion Test Facility (LSVCTF) and the Containment Test Facility (CTF) at Whiteshell Laboratories (WL, AECL), at Chalk River Laboratories (CRL, AECL) and international facilities (H2PAR and REKO-1 – France, THAI – Germany).

PAR catalyst is potentially susceptible to degradation/poisoning by volatile organic compounds (VOCs). Due to low concentrations of VOCs in nuclear reactor containment, periodic regeneration of the PAR catalyst plates may be necessary. AECL's whole plate tester (WPT) is used to inspect catalyst plates in-service to determine if they require regeneration.

In addition to the current qualified designs, AECL is currently completing qualification of a larger design. AECL has supplied PARs to France, Finland, Ukraine, South Korea and is currently being deployed in Canadian nuclear power plants.

The intention of this paper is to discuss the qualification testing performed on the AECL PAR and the on-site, in-service testing required to assure the PAR is ready for service as well as to provide an update on the commercial accomplishments of AECL PARs. Prior to this, the characteristics, features and performance of the recombiner and the AECL PAR test facilities will be described.

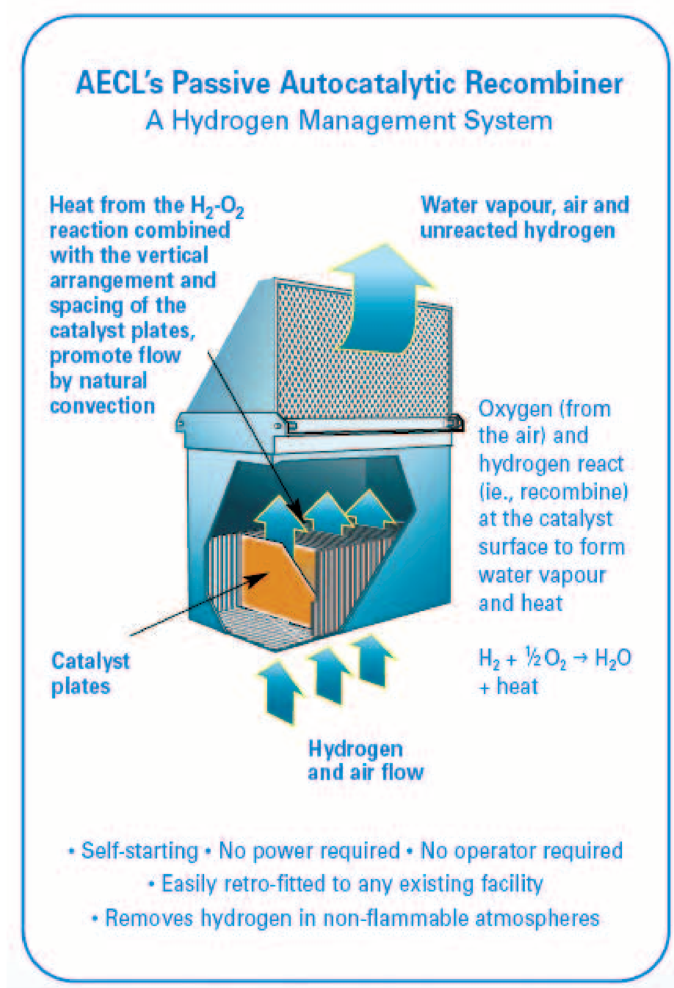

Figure 1: Principle of PAR Operation

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2. AECL PAR characteristics, features and performance

AECL's PAR design consists of flat rectangular catalyst plates arranged vertically in an open ended box (housing), with an attached cover. Oxygen and hydrogen react at the surface of the catalyst producing water vapour and heat. The heat generated at the catalyst surface combined with the PAR geometry creates a natural convective flow through the recombiner without external power or operator action. Warm humid air with unreacted hydrogen is exhausted through the PAR outlet.

Owing to its compact design, the PAR can be easily installed individually or in groups, and the modular design facilitates distribution of the required hydrogen removal capacity through reactor containment.

The catalysts used in PARs are proprietary AECL formulations developed for application in radioactive environments. Two catalyst formulations, Type 89-24 and Type 99-11, are available. The catalysts have high activity for hydrogen oxidation, are not deactivated by water vapour or steam, operate over a wide range of temperatures (13 -750 °C) and are unaffected by exposure to high radiation. The catalysts are wet-proofed using a proprietary procedure. Water is repelled, but hydrogen and oxygen are able to diffuse to the active sites for the recombination reaction to occur.

PAR performance is characterized by two parameters: hydrogen removal rate (capacity) and self-start threshold.

2.1 Hydrogen removal rate (capacity)

Hydrogen removal rate (capacity) is defined as the amount of hydrogen that one PAR unit removes per unit of time (usually expressed in kg/h or g/s with reference to temperature and pressure at a specified concentration of the limiting constituent). The AECL PAR capacity was studied as a function of temperature (286-378 K), pressure (90-400 kPa(abs)) and hydrogen concentration (0.5-6.0 vol. %). For oxygen-limited gas mixtures, the capacity is a function of oxygen concentration. PAR capacity increases with increasing pressure and limiting reactant concentration, and decreases slightly with increasing temperature.

Capacity is insensitive to the presence of diluents such as steam, CO2, or N2 as long as an above-thestoichiometric amount of oxygen required for recombination is available.

2.2 Self-start threshold

Self-start threshold is the minimum hydrogen concentration required to develop a self-sustained convective flow through the recombiner at a given (ambient) temperature. The self-start hydrogen concentration decreases with an increase in the ambient temperature. A PAR containing new (or regenerated) catalyst will self-start at 2% hydrogen by volume in a water vapour saturated atmosphere at 20°C within 30 minutes.

PAR catalysts are susceptible to degradation, as are all noble metal catalysts. This can be understood as the result of phenomena that remove active sites from the catalyst surface -for instance, the occupation of active catalyst sites by adsorbed molecules other than O2 and H2.

Airborn volatile organic compounds (VOCs) might be present in nuclear containment air. They may originate from chemicals (paints, solvents, lubricants, glues, etc.) used during reactor maintenance outages. VOCs can also be released from painted surfaces and insulation, especially with heating during a reactor restart.

VOCs can adsorb on the surface of any noble metal catalyst taking up some of the available active sites. This will lead to a temporary deactivation/degradation of the catalyst, thereby affecting PAR self-start. The amount of adsorbed VOCs will decrease with increasing ambient temperature. Adsorbed VOCs can be removed with heat generated by the exothermic reaction between hydrogen and oxygen on the catalyst surface or heating the catalyst in air in an oven. With the application of heat, eventually all VOCs will desorb from the catalyst and the original catalyst activity and performance will be restored.

AECL's PAR containing new catalyst plates will self-start at $\leq$ 2% hydrogen, $\leq$ 20°C, 1 bar and 100% RH [1]. However, after exposure to nuclear containment air, the active sites of the PAR catalyst may become occupied by VOCs, temporarily affecting the PAR's ability to self-start. The condition of the catalyst will depend on the concentration of VOCs in the containment air, duration the catalyst has been exposed in containment and the containment temperature. Self-start after exposure to VOCs might require higher than 2% hydrogen concentration and/or higher than 20°C to rapidly self-start. If the catalyst is exposed to hydrogen concentration for a longer period of time, the recombiner will self-start at a lower hydrogen concentration and/or a lower ambient temperature. For a given catalyst condition (degradation level) the hydrogen concentration required for PAR self-start will decrease exponentially with increasing temperature [2]. Once started the PAR operates at the design capacity. Therefore, the PAR capability to self-start (readiness for service) is the critical characteristic to monitor.

AECL has demonstrated that a degraded catalyst plate can be regenerated to its initial activity by self-starting (in the presence of hydrogen) or by heating in air. Furthermore, it was demonstrated that the heat generated by one new (or regenerated) catalyst plate can regenerate the adjacent catalyst plates in a PAR on exposure to 2% hydrogen. In turn, the heat from the newly regenerated plates would regenerate their adjacent plates creating a "domino effect" and ultimately regenerating all catalyst plates in the PAR [2]. Thus, periodic regeneration of one or more starter plates would ensure the uninterrupted PAR availability for service.

3. AECL PAR Testing Facilities

The Large Scale Vented Combustion Test Facility (LSVCTF, Figure 2), located in Whiteshell Laboratories in Manitoba, is a 10 m long, 4 m wide and 3 m high rectangular enclosure with an internal volume of 120 m3. The facility is designed to be versatile so that many geometrical configurations can be achieved. The facility can be subdivided into two or three compartments using partitions, which have openings to allow internal venting. The facility incorporates extensive capabilities for instrumentation, data acquisition, gas sampling and analysis. Other features of the facility include operation at temperatures exceeding 100°C for extended time intervals and remote operation to ensure safety of the personnel. Test conditions in the facility can be controlled and measured accurately. Instrumentation and facility modifications can be performed quickly due to easy access to the interior of the test chamber.

The Containment Test Facility (CTF) sphere (Figure 3) has an internal volume of 6.6 m3, is rated for pressures up to 10 MPa, and can be trace-heated. The facility has systems for the controlled addition of hydrogen, oxygen, nitrogen and air. The sphere can be steam trace heated and cooled to a limited degree. It is leak-tight and thus allows experiments at elevated pressures, low oxygen, and/or the presence of selected gases. The sphere is ideal for long-term (several days) experiments where it is desired to maintain conditions for the test duration. Test conditions in the CTF sphere can be controlled and measured accurately.

Figure 2: Large-Scale Vented Combustion Test Facility

4. AECL PAR Qualification

The AECL PAR was subjected to cumulative stressors that simulated the operational conditions the recombiner is expected to be exposed to during its life-

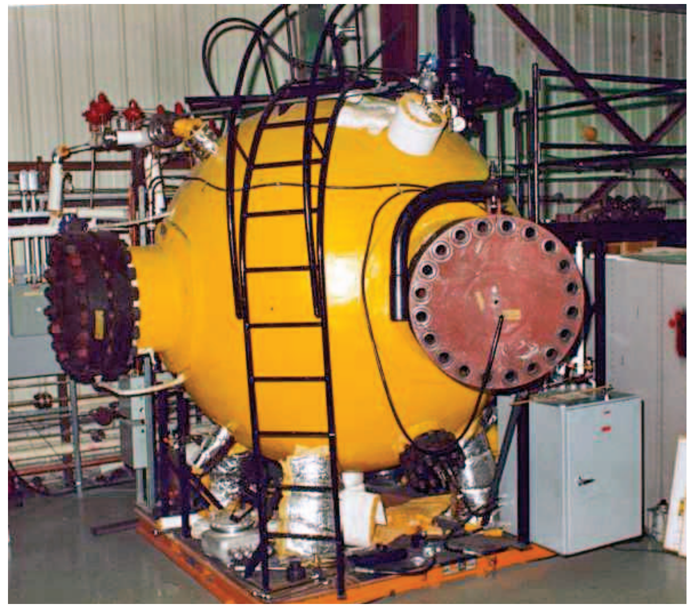

Figure 3: Containment Test Facility

time. Qualification also included subjecting the PAR to potential post-accident conditions. Baseline functional tests were performed to determine the PAR performance prior to applying the stressors. Subsequent intermediate and final functional tests were carried out to demonstrate the PAR performance after exposure to the cumulative stressors.

Stressors applied cumulatively to the PAR included thermal and radiation aging, long-term exposure to hydrogen and seismic testing. Additional tests using the same PAR housing and catalyst plates included functional tests to determine the effect of dousing spray chemicals, the effect of high pressure on capacity, and the effect of low oxygen on self-start. The effect of fuel aerosols on PAR capacity was tested using a reduced-size PAR unit in the H2PAR facility in France [1].

Poisoning tests were performed to examine the separate effects of post-accident chemicals on PAR catalyst samples and the full scale PAR. The chemicals include iodine, methyl iodide, hydrazine, chlorine, hydrochloric acid, formaldehyde, benzene, cable/kerosene fires, carbon dioxide and carbon monoxide. The recombination activities (recombination rates) of the exposed samples were compared to the activities of new catalyst [1].

The recombiner was evaluated under CANDU operating conditions to study the effect of VOCs present in the containment air on the catalyst by installing trial PARs in CANDU reactors.

Functional testing, including thermal aging and tests with sprays, was conducted in the LSVCTF and CTF at AECL-WL. Poisoning tests were carried out at AECL-CRL. Radiation aging, seismic qualification and tests including exposure to fuel aerosols were performed by independent laboratories.

Table 1: Summary of AECL PAR Qualification

Qualification Aspect	Operability
Pressure	1-4 bar(abs)
Temperature	• 13-108°C (capacity measurements) • Up to 750°C (functionality)
Hydrogen concentration	>0.5% by volume
Relative humidity	Up to 100%
Radiation	370-480 kGy gamma; small-scale activity tests after exposure to 2000 kGy gamma
Post-accident H2 transient	Yes (24 h of postulated post-LOCA H2 transient in a CANDU reactor)
Seismic acceleration	9.5 g (horizontal) and 6.3 g (vertical)
Thermal aging	40 years at 50°C
Fuel aerosols and vapours	Yes (simulated PWR core fusion)
Hydrogen burns	Yest (ignition tests at 7.5-8% H_2 by volume)
Cable/kerosene fires	Yes
Sprays	
• Before hydrogen release	Yes
• After hydrogen release	Yes
• Water	Yes
• Boric acid, borax, potassium hydroxide	Yes (16 g/kg_{water} boric acid, 7.5 g/kg_{water} borax, 0.185 g/kg_{water} KOH)
• Tri-sodium phosphate (TSP), lithium hydroxide	Yes (120 mg/kg_{water} TSP, 50-100 mg/kg_{water} LiOH)
• Sodium hydroxide	Yes (0.6 wt%)
Low oxygen concentration	Yes (1-2% O_2 by volume)
Post-accident chemicals (iodine, methyl iodide, hydrazine, chlorine, hydrochloric acid)	Yes(5.0 mg/m^3 iodine, 5.0 mg/m^3 CH_3I, 100 mg/L N_2H_4, 40 mg/m^3, Cl_2, and 10 g/m^3 HCl)
After long-term exposures to plant operating conditions	Yes (up to 42 months)

A summary of AECL PAR qualification is given in Table 1.

5. AECL PAR In-Service Inspection

The AECL recombiner requires no special maintenance. However, periodic testing of the catalyst is required to ensure the PAR availability for service, i.e. its capability to self-start at the required station-specific conditions of temperature and hydrogen concentration. To perform on-site periodic testing, AECL has developed the whole plate tester (WPT) – see Figure 4.

Figure 4: Whole Plate Tester (WPT)

The WPT is comprised of a temperature controlled enclosure (oven chamber) where a PAR catalyst plate is inserted. A mixture of 2% hydrogen (by volume) in air is admitted into the oven chamber and over the catalyst plate at a controlled flow rate. Six infrared sensors monitor the temperature increase of the catalyst plate as a function of time. "PASS" or "FAIL" is indicated relative to the station-specific requirement for PAR self-start. A "PASS" denotes the plate will meet the requirement. However, it does not give an indication of the actual degradation of the catalyst. Thus, the plate must be regenerated before re-installation. A "FAIL" indicates that the plate has degraded beyond the station-specific requirement. Therefore, the inspection schedule may need to be modified to ensure uninterrupted PAR availability for service.

AECL recommends performing the following activities during every maintenance outage:

- Visually inspect a few plates per PAR
- Test three starter plates per PAR in the WPT
- Regenerate (or replace with regenerated/new catalyst plates) the starter plates in each PAR

If the required self-start temperature is equal to or exceeds 100°C, the VOCs are not of great concern, as it has been determined through years of research that the AECL PAR will self-start at 2% hydrogen by volume or less regardless of the catalyst degradation level.

6. AECL PAR Commercial Experience

The AECL PAR has been supplied to CANDU reactors in Canada and PWR and VVER reactors in France, Finland, Ukraine and South Korea. Two models (PAR1 and PAR2) of the AECL recombiner are currently qualified and installed in nuclear power reactors. A third (PAR3) design with a larger capacity is currently being qualified.

7. Conclusion

The AECL PAR is a device which employs a catalyst to facilitate the reaction between hydrogen and oxygen producing water and heat. It is a passive system which self-starts/self-feeds and does not require power or operator action. It has undergone extensive qualification testing at AECL's hydrogen test facilities and international facilities. The PAR requires in-service testing using the WPT and periodic regeneration due to the susceptibility of noble metal catalyst to degradation by VOCs. Since 2003, AECL has supplied PARs globally.

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GENERAL news

(Selected by Fred Boyd from open sources)

OPG awards contracts for Darlington refurbishment

On March 1, 2012 Ontario Power Generation announced that it had issued contracts for the first phase of the planned refurbishment of the Darlington Nuclear generating Station.

OPG has awarded a two-phase contract to plan for and then replace major components of the four reactors at Darlington. The contract for more than $600 million to a joint venture of SNC-Lavalin Nuclear Inc. and Aecon Construction Group Inc. is one of several that will be awarded for the refurbishment of the facility.

The first phase of the project will involve planning for the removal and replacement of the 480 pressure tubes and calandria tubes, and 960 feeder pipes for each of the station's four reactors. The second phase would involve the execution of the plan.

OPG has now awarded a contract to SNC-Lavalin and Aecon to carry out the definition phase of the refurbishment project. Aecon will now construct a full-scale reactor mock-up where key elements of the project can be simulated and tested prior to work beginning on the actual reactors. Meanwhile, SNC-Lavalin will develop specialized tooling required for the project. The two companies will also develop of a detailed scope, schedule and budget for the execution phase, as well as procure components for the first reactor unit to be refurbished.

The joint venture between Aecon and SNC-Lavalin will see them concentrate respectively on construction and fabrication services, and tooling and engineering. Project management and procurement will be provided jointly and the firms will share equally the costs and profits from the 'execution' phase of the refurbishment. The definition phase is expected to run from 2012 to 2016 with completion of the refurbishment scheduled for 2023.

IAEA endorses CNSC response to Fukushima

On March 5, 2012, the International Atomic Energy Agency (IAEA) released the results of its Integrated Regulatory Review Service (IRRS) mission in November 2011 of the response of the Canadian Nuclear Safety Commission (CNSC) to the March 2011 events at Japan's Fukushima Daiichi Nuclear Power Station.

The IRRS mission concluded that the CNSC's response to the March 2011 events at Fukushima was prompt, robust and comprehensive, and is a good practice that should be used by other regulatory bodies.

The assessment, which was a peer review by an international team of nuclear regulatory experts from seven countries, included:

- a follow-up visit to evaluate the CNSC's implementation of the action plan from a June 2009 IRRS Peer Review
- an assessment of the CNSC's response to the spring 2011 events at the Fukushima Daiichi Nuclear Power Station
- an assessment of the CNSC's regulatory practices related to packaging and transport of nuclear substances.

The report also noted that:

- the recommendations and suggestions from the 2009 IRRS mission were systematically addressed through active senior management commitment.
- the CNSC has performed a systematic and thorough review of the implications and lessons learned from the March 2011 accident in Fukushima Japan, ensuring that Canadian nuclear power plants are safe.
- the regulatory framework for the transport of radioactive materials is well established and commensurate with the large scope and volume of transport activities in Canada.

The English version of the IRRS report and the CNSC Management Response are available on the CNSC Web site. The French translation of the report will be posted at a later date.

Cameco facilities receive 10 year licences

Ob February 29, 2012, the Canadian Nuclear Safety Commission announced that it had renewed the Operating Licences of three facilities of Cameco Corporation for a period of 10 years.

The facilities are:

- Cameco's Nuclear Fuel Facility in Blind River, Ontario
- Cameco's Uranium Conversion Facility in Port Hope, Ontario
- Cameco's Fuel Manufacturing Facility, also in Port Hope

The CNSC had held public hearings on November 3, 2011 in Ottawa and on January 19, 2012 in Port Hope. There were 38 intervenors.

Cameco's Blind River facility in northern Ontario is the world's largest uranium refinery. It accepts uranium concentrates from Cameco's mines in northern Saskatchewan and around the world.

The Conversion facility accepts the UO_3 from Blind River and converts it to UO_2 for CANDU fuel and to UF_6 for feed to enrichment facilities around the world.

The Fuel Manufacturing facility manufactures fuel for CANDU reactors.

Cameco also has a metal fabrication plant in Cobourg, 10 km east of Port Hope, which manufactures parts for the CANDU fuel bundles and other related items.

Government seeks Expression of Interest in AECL

On February 9, 2012, the Minister of Natural Resources, Joe Oliver publicly announced a process inviting Expression of Interest in the activities of Atomic Energy of Canada Limited's (AECL's) Nuclear Laboratories.

The announcement stated the process is to allow the Government to benefit from the experiences of organizations, domestic or international, involved in the management or restructuring of nuclear science and technology or radioactive waste management.

The information gathered through this process will help inform the restructuring process of the AECL Nuclear Laboratories, which the government states is a critical step to further strengthen Canada's nuclear industry while reducing taxpayers' exposure to financial risks in this sector.

The due date for submissions is April 2, 2012.

AECL's Nuclear Laboratories include two main sites: Chalk River Laboratories (CRL), located in the Province of Ontario, 190 km northwest of Ottawa, and Whiteshell Laboratories, located at Pinawa, Manitoba.

Aerial view of Chalk River Laboratories

The Laboratories are home to researchers with unique capabilities and expertise.

Specialized facilities support key nuclear science and technology priorities that include innovation for industry, safety, security, health, environmental, waste management and clean energy technologies.

The announcement stated that the Government of Canada will continue its role in maintaining safety, security and environmental stewardship in all aspects of the nuclear industry. The Canadian Nuclear Safety Commission (CNSC), Canada's nuclear regulator, will continue to regulate all parts of the entire nuclear industry in Canada.

Public Works and Government Services Canada (PWGSC), on behalf of NRCan, has issued the RFEOI which can be found on the MERX website at http://www.merx.com/.

Large contracts for Sellafield decommissioning

Sellafield Ltd., the company created to decommission the Sellafield site in the UK has awarded a contract worth some £1.5 billion ($2.3 billion) over 15 years to two joint ventures for design services related to the large site. One is known as Axiom and made up of Amec, Assystem, Jacobs Engineering Group and Mott MacDonald. The other is called Progressive Alliance and made up of Babcock and URS Corp.

This is the first of some £9 billion ($14.2 billion) in long-term contracts to support decommissioning at the UK's Sellafield site.

Axiom and Progressive Alliance will supply design support services to Sellafield Ltd as it goes about decommissioning a wide range of facilities at the site. The 'true alliance-style framework contract' represents a new approach to contracting brought in by Sellafield Ltd's parent body, Nuclear Management Partners - itself a joint venture of Amec, URS Corp and Areva.

This web of nuclear engineering firms has called the contract a 'Design Services Alliance'. It will cover design and safety assessments, some construction, work packages for refurbishment jobs as well as post-operational clean-out and decommissioning support. Sellafield Ltd said the work is "structured across eight lots over four capability areas, including mechanical handling; process plant; control, electrical and instrumental; and civil, structural and architectural systems. The contract is projected to extend for 15 years.

The UK government's policy has been to own as few nuclear assets as possible, spin off former state companies and create frameworks for private enterprise to meet its goals for clean-up or power generation. Nevertheless, it must maintain ownership of legacy wastes and facilities from the former national program that pioneered much nuclear research and the early use of nuclear power. In 2005 it created the Nuclear Decommissioning Authority to own the legacy sites and direct government funding towards the ultimate goal of clean-up, overseeing a range of contracts across fuel cycle, research and Magnox power generation site groupings.

Sellafield Ltd said that the contract is the first of an anticipated £9 billion ($14.2 billion) worth of long-term contracts" it will let "over the next two years.

Oldbury plant enters retirement

On February 29, 2012, the UK government announced that Unit 1 at the UK's Oldbury plant, a 217 MWe Magnox unit, had been closed after 44 years of power generation. It was the world's oldest operating nuclear power reactor.

Construction of a new plant is planned at the site.

USNRC issues first licence for new build

On February 9, 2012, the US Nuclear Regulatory Commission voted to issue combined Construction and Operating Licences (COL) for Southern Nuclear Operating Company's (SNC) to build and operate two Westinghouse AP1000 reactors at the Vogtle site in Georgia. These are the first COLs to be issued by the USNRC.

The Commission imposed a condition on the COLs requiring inspection and testing of squib valves, important components of the new reactors' passive cooling system.

The COLs will authorize SNC to build and operate two AP1000 reactors at the Vogtle site, adjacent to the company's existing reactors approximately 26 miles southeast of Augusta, Ga. NRC construction inspectors have been on-site since April 2010, examining SNC's activities to prepare the plant's foundation under a Limited Work Authorization the NRC issued on Aug. 26, 2009.

SNC submitted its COL application on March 28, 2008, and supplemented the application on Oct. 2, 2009. The NRC's Advisory Committee on Reactor Safeguards (ACRS) independently reviewed aspects of the application that concern safety. The ACRS provided the results of its review to the Commission in a report dated Jan. 24, 2011. The NRC completed its environmental review and issued a Final Supplemental Environmental Impact Statement for the Vogtle COLs on March 24, 2011 and issued the FSER on Aug. 9, 2011.

The NRC had certified Westinghouse's amended AP1000 design on Dec. 30, 2011. The AP1000 is a 1,100 megawatt electric pressurized-water reactor that includes passive safety features that would cool down the reactor after an accident without the need for electricity or human intervention.

Point Lepreau Operating Licence renewed

On February 17, 2012 , the Canadian Nuclear Safety Commission (CNSC) announced today its decision to renew the Power Reactor Operating Licence issued to New Brunswick Power Nuclear (NBPN) for its Point Lepreau Nuclear Generating Station, for the period between February 17, 2012 until June 30, 2017.

In addition, the Commission granted NBPN permission to proceed with fuel reload and restart of the reactor, following its long refurbishment program..

The Commission, in making its decision, considered information presented for a public hearing held on October 6, 2011 in Ottawa, Ontario and on December 1 and 2, 2011 in Saint John, New Brunswick. During the public hearing, the Commission received and considered submissions from NBPN and 37 intervenors, as well as CNSC staff's recommendations.

With this decision, the Commission has recommended the completion of a site-specific seismic hazard assessment. The Commission further requires that NBPN share the results of this assessment as part of its public information program.

The Commission noted that CNSC staff will present its annual Integrated Safety Assessment of Canadian Nuclear Power Plants, including the Point Lepreau facility, at a public proceeding of the Commission in approximately August of each year, and that the public will have an opportunity to provide written comments on the report.

OPG Reports 2011 Financial Results

On March2, 2012 Ontario Power Generation Inc. (OPG reported its financial and operating results for the year ended December 31, 2011. Net income for the year was $416 million compared to net income of $649 million for the year ended December 31, 2010.

Following are excerpts from the official media release.

OPG received an average price of 5.3 cents per kilowatt hour, which had a moderating effect on the price of electricity in Ontario. *(This compares with the average cost of wind generation, which, by provincial policy, displaced some of OPG's potential production, of about 12 cents per kwhr.)*

OPG's income before income taxes from the electricity generation business segments was $680 million for the year ended December 31, 2011 compared to $679 million for the same period in 2010.

The Regulated – Nuclear Waste Management business segment recorded a loss before income taxes of $194 million for the year ended December 31, 2011 compared to income before income taxes of $8 million in 2010. This decrease was primarily due to lower earnings from the Nuclear Funds as a result of a decline in the valuation levels of global financial markets in 2011.

Generating and Operating Performance

Total electricity generated in 2011 of 84.7 TWh decreased from 2010 generation of 88.6 TWh. The reduction of 3.9 TWh was primarily due to lower thermal generation, partially offset by higher generation from OPG's nuclear and hydroelectric stations. Nuclear production in 2011 was 48.6 TWh, an increase of 2.8 TWh compared to 2010. The increase was primarily as a result of excellent performance achieved at the Darlington generating station.

In 2011, Darlington achieved the lowest level of unplanned outages in its history, with an excellent unit capability factor of 95.2 per cent. The capability factor for the Pickering A station in 2011 was 67.9 per cent compared to 62.4 per cent in 2010. In 2011, five of our ten units operated at a capability factor of greater than 90 per cent, and two other units operated at a capability factor greater than 80 per cent.

Generation Development

OPG is undertaking a number of generation development projects aimed at significantly contributing to Ontario's long-term electricity supply requirements. The status of these capacity expansion or life extension projects is as follows:

Nuclear

- In February 2010, OPG announced its decision to commence the definition phase for the refurbishment of the Darlington nuclear generating station to extend the operating life of the station by approximately 30 years. In 2011, the technical scope was finalized, and the Environmental Assessment ("EA") and final Integrated Safety Review ("ISR") were submitted to the Canadian Nuclear Safety Commission ("CNSC"). The ISR will be subject to a formal review by the CNSC which is expected to be completed by mid-2013.
- During 2011, OPG continued with initiatives in preparation for new nuclear units at Darlington. Public hearings on the EA and "Licence to Prepare Site" were completed in early 2011. In August 2011, the Joint Review Panel submitted its report to the federal Minister of the Environment, concluding that the project is not likely to cause significant adverse environmental effects, given mitigation. The federal government will now prepare its response for approval by the Governor in Council, with a final determination of whether or not the EA should be accepted.
- OPG is undertaking a coordinated set of initiatives to evaluate the opportunity to continue the safe and reliable operation of its Pickering B nuclear generating station for approximately an additional four to six years beyond its nominal end of life. In 2010, OPG submitted a Pickering B Continued Operations Plan to the CNSC. At a public meeting in March 2011, the CNSC staff presented their review of the Pickering B Continued Operations Plan and indicated that there were no significant regulatory or safety issues. By the end of 2012, OPG expects to have completed the necessary work to demonstrate with sufficient confidence that the pressure tubes will achieve the additional life as predicted.

Environmental Panel appointed for LIW repository

On January 24, 2012, Peter Kent, federal Minister of the Environment and Michael Binder, President of the Canadian Nuclear Safety Commission (CNSC), announced the establishment of a three-member joint panel to review Ontario Power Generation's proposed project to construct and operate a facility for the long-term management of low and intermediate level radioactive waste (LIW) in Ontario.

The Panel will be chaired by Dr. Stella Swanson and Drs. James F. Archibald and Gunter Muecke have been appointed as members of the Joint Review Panel.

Dr. Swanson owns the consulting company Swanson Environmental Strategies Ltd. in Calgary. Her career has included management of the Aquatic Biology Group at the Saskatchewan Research Council and consulting positions with SENTAR Consultants and Golder Associates Ltd. Dr. Archibald is a professor in the Robert m. Buchan Department of Mining at Queen's University. Dr. Muecke is retired from the School of Resource and Environmental Studies at Dalhousie University

Under the agreement between Environment Canada and the CNSC, the Joint Review Panel will conduct an examination of the environmental effects of the proposed project to meet the requirements of the Canadian Environmental Assessment Act. The Panel will also obtain the information necessary for the consideration of the licence application to prepare a site and to construct the deep geologic repository facility under the Nuclear Safety and Control Act.

The agreement, along with more information on the project, is available on the Canadian Environmental Assessment Registry at http://www.ceaa-acee.gc.ca/ reference # 06-05-17520 as well as on the Web site of the CNSC at http://www.nuclearsafety.gc.ca/.

Ontario Power Generation is proposing to construct and operate a facility for the long-term management of low and intermediate level radioactive waste at the Bruce Nuclear Site. The project will hold waste currently in interim storage on the Bruce Nuclear Site in the Western Waste Management Facility, as well as the wastes that continue to be produced by the operation of nuclear generating stations at Bruce, Pickering and Darlington.

Low level waste consists of industrial items that have become contaminated with low levels of radioactivity during routine clean-up and maintenance activities at nuclear generating stations. *Intermediate level radioactive waste* consists primarily of used nuclear reactor components, ion-exchange resins, and filters used to purify reactor systems.

Used nuclear fuel will not be stored or managed in the proposed repository.

Point Lepreau Generating Station Refurbishment Project Update

New milestone for the Point Lepreau Generating Station– all 760 lower feeder installations completed

The Refurbishment Project team has successfully completed the 760 lower feeder installations at the Point Lepreau Generating Station (PLGS), the last major construction activity of the project. The installation of the lower feeders was completed on March 1, 2012, in advance of the May 2012 target set in the revised project schedule.

The feeder installation teams have been working around the clock since December 2011 to complete these project activities safely.

The lower feeder installations were similar to completing a complex, three-dimensional puzzle that needs to be assembled in a defined sequence as each feeder is nested together with the proper clearances.

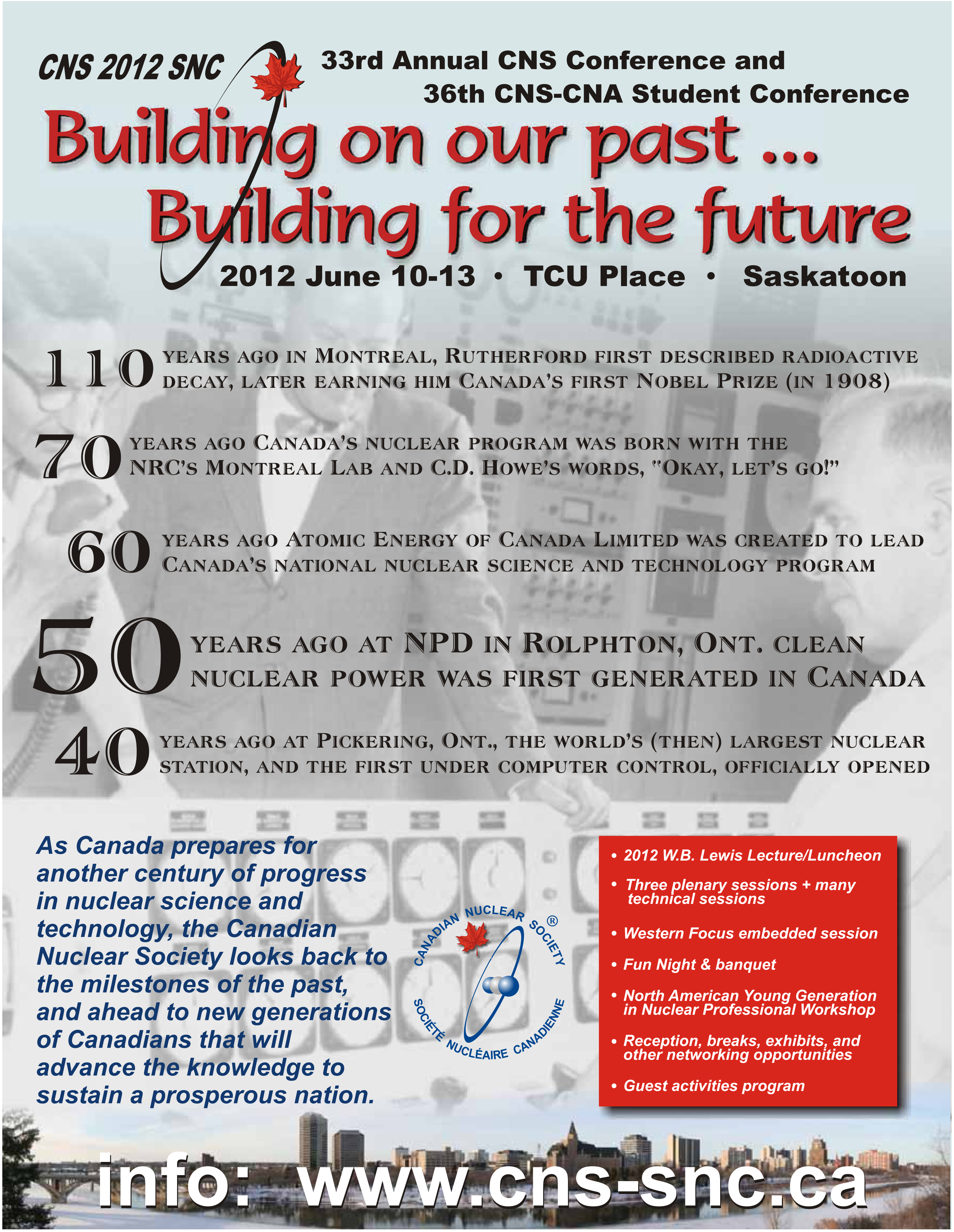
CANDU reactors use feeder pipes to transport heavy water to and from the fuel channels to transfer the heat generated by the fuel into the boilers. In the boilers, steam is produced to turn the turbine and ultimately to turn the generator to create electricity.

"A lot of good planning went into the lower feeder installations, including the capture of knowledge from previous refurbishment projects in Canada and overseas," said Rod Eagles, NB Power Refurbishment Project Director. "This achievement brings us another step closer to restarting the Point Lepreau Generating Station."

The next major restart activity at PLGS is loading new fuel in the reactor, which is scheduled to begin this month. As announced on February 17, 2012, the Canadian Nuclear Safety Commission (CNSC) granted a five-year Power Reactor Operating Licence to PLGS. The licence decision included the Commission's permission to proceed with fuel load and other restart activities once NB Power has progressed and completed the required commitments for this fuelling activity to commence and received confirmation from the CNSC designated officer.

In addition to preparing for fuel load, there are many other diverse activities taking place at the Station in preparation for returning the Station to service and generating electricity. The sense of excitement continues to build among everyone involved in completing the work and ensuring the safe transition back to operation.

After the commissioning activities are completed, the Station is expected to return to service by the fall of 2012 delivering safe and reliable power to New Brunswick for the next 25 to 30 years.


CNS 2012 SNC
33rd Annual CNS Conference and
36th CNS-CNA Student Conference
Building on our past ...
... Building for the future
2012 June 10-13 • TCU Place • Saskatoon
110 years ago in Montreal, Rutherford first described radioactive decay, later earning him Canada's first Nobel Prize (in 1908)
70 years ago Canada's nuclear program was born with the NRC's Montreal Lab and C.D. Howe's words, "Okay, let's go!"
60 years ago Atomic Energy of Canada Limited was created to lead Canada's national nuclear science and technology program
50 years ago at NPD in Rolphton, Ont. clean nuclear power was first generated in Canada
40 years ago at Pickering, Ont., the world's (then) largest nuclear station, and the first under computer control, officially opened
As Canada prepares for another century of progress in nuclear science and technology, the Canadian Nuclear Society looks back to the milestones of the past, and ahead to new generations of Canadians that will advance the knowledge to sustain a prosperous nation.
Canadian Nuclear Society ®
Société Nucléaire Canadienne
• 2012 W.B. Lewis Lecture/Luncheon
• Three plenary sessions + many technical sessions
• Western Focus embedded session
• Fun Night & banquet
• North American Young Generation in Nuclear Professional Workshop
• Reception, breaks, exhibits, and other networking opportunities
• Guest activities program
info: www.cns-snc.ca

CNS news

CNS appoints an Executive Director

Following is the announcement by CNS President Frank Doyle on the appointment of Dr. Benjamin Rouben as the Society's first Executive Director

[I am] pleased to announce that the Canadian Nuclear Society (CNS) Council has appointed Dr. Benjamin (Ben) Rouben, Ph.D., FCNS, as the Society's first Executive Director, to serve initially on a part-time basis. This is felt to be a prudent and fiscally responsible first step to help the Society move forward with key elements of its strategic plan and to be better positioned to participate effectively in the new era in the nuclear science and technology community in Canada. The appointment of Dr. Rouben demonstrates the CNS' commitment to be part of this new direction for the future.

Dr. Rouben, as Executive Director, will provide focus and direction for the CNS to increase expertise as a professional society and to help build a sustainable future for the CNS.

Dr. Rouben received his B.Sc., Mathematical Physics (First Class Honours), in 1965, from McGill University in Montréal and his Ph.D. in 1969 in Theoretical Nuclear Physics from the Massachusetts Institute of Technology. Following graduation, Dr. Rouben engaged in research in theoretical nuclear physics as a Research Associate in Nuclear Structure in the Laboratoire de Physique Nucléaire, Université de Montréal. In 1975, Dr. Rouben began his career in the Reactor Physics Branch at Atomic Energy of Canada Ltd. (AECL).

During his long and distinguished career, Dr. Rouben contributed to the development and understanding of reactor core physics in his roles as Reactor Physicist, Section Head and Branch Manager. He remains a strong advocate of AECL's CANDU design and has contributed to more than fifty scientific papers, including Journal articles.

Dr. Rouben has been a major contributor to the success of the CNS. He is a `Fellow' of the CNS and served as President (1997-1998) and, more recently, as the CNS Executive Administrator and Chair of the Membership Committee. He has also chaired, and is a member of, ANS International Committees.

Dr. Rouben also serves as Secretary/Treasurer of the University Network of Excellence in Nuclear Engineering (UNENE). He is an Adjunct Professor at McMaster University and the University of Ontario Institute of Technology, and Professor in the UNENE Master of Engineering program.

The wealth of experience and commitment that Ben Rouben brings to the CNS will help assure the infrastructure and controls are in place to execute the CNS' Strategic Plan with integrity and efficiency.

The CNS Executive and Council-at-large offered their full support and ask all members of the Society to welcome Ben to this position and to become engaged in developing an expanded, more visible, more relevant Society. Collectively, all members can sustain the future of the society and indeed the future of nuclear in Canada.

Meneley made an EIC Fellow

Daniel Allison (Dan) Meneley, a past-president of the Canadian Nuclear Society and former Chief Engineer at Atomic Energy of Canada Limited, was installed as a Fellow of the Engineering Institute at the EIC Awards Banquet held in Ottawa, Saturday, February 25, 2012.

The short form of his citation simply states "For contributions to nuclear engineering and science".

The full citation reads:

Daniel Allison Meneley has combined his extensive career as a practising engineer in Canada and the United States with an impressive series of appointments in academia.

Dan's undergraduate and post-graduate training provided him with a solid basis upon which to undertake a wide variety of assignments including several that demanded an intellect and unending determination to master some of the most complicated engineering challenges including nuclear reactor kinetics, fluid dynamics and thermalhydraulics. Dan's international contri-

Tony Bennett, president of the Engineering Institute of Canada, (R) presents Dan Meneley with the citation certificate naming Dan as a Fellow of the EIC at the EIC Awards Ceremony in Ottawa, February 25, 2012.

butions in nuclear engineering and science have won him acclaim. His wise counsel is in constant demand by his peers worldwide.

In 2006 he was appointed Chair of the NRU (Research Reactor and Radioisotope Production Reactor) Severe Accident Assessment Team. In 2007, the Government of Canada called upon Dan to report to Parliament on the Safety Evaluation of NRU.

We are honoured this evening to recognize Daniel Meneley's many contributions to the nuclear industry in Canada.

Dan was made a Fellow of the Canadian Nuclear Society in 1998 and of the Canadian Academy of Engineers in 2008.

He is currently an Adjunct Professor at the School of Energy Systems and Nuclear Science of the University of Ontario Institute of Technology.

News from Branches

ALBERTA – Duane Pendergast

Duane Bratt reports that he has established a course titled; "The Science and Politics of Nuclear Energy" at Mount Royal University in Calgary. During the winter session of 2011 there were only 5 registered students in a 30-seat course. Enrolment has expanded to 31 registered students in a 30-seat course for the winter session of 2012. It is encouraging to learn some Alberta youth are concerned with future energy needs and want to learn more about viable options and replacements for non-renewable energy sources.

Nigel Fitzpatrick made a presentation on "Hybrid and Electric Vehicle Technology – Developed in BC" to the Pacific Energy Innovation Association Energy on December 7 and will be speaking to "The State of the Electric/Hybrid Vehicle Industry" at the "Cool North Shore" climate club's "Cool Drinks" monthly get together on January 17. Nigel has long been interested in the role electric cars could play in converting the transportation system to nuclear energy.

CHALK RIVER – Ruxandra Dranga

Education and Outreach:

On December 23rd, Bryan White and Ruxandra Dranga met with AECL representatives to discuss the venue for the planetarium that we want to sponsor during Summerfest. AECL has kindly agreed to allow us to use the Voyageur Room at Keys Campus for this occasion, at no cost. AECL employees will watch the entrance doors to ensure that the public doesn't wonder inside the building unescorted. Also, the location of the Voyageur Room is very close to other Summerfest activities.

Afterwards, Bryan discussed with the Summerfest Committee and Science North, and we have secured the Planetarium for this summer. The CNS CRB already has funds from FY 2011 to provide the deposit ($926.00). The remaining funds ($2778.14) will be needed during the summer.

A projector will be available during this event so that CNS ads can be displayed while people enter and leave the room. The CNS banners will also be posted around the room.

On January 9th, Blair Bromley attended a meeting with the Renfrew County Science Fair organizing committee to discuss the possibility of creating a new "Special Award in Nuclear Science and Technology". We want to encourage students to have more projects related to nuclear science and technology.

Blair also discussed the future collaboration between the CNS CRB and the RCSF to include a poster/draw-

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ing contest for Grade 6, 7 and 8 students. The poster/drawing contest will be organized and judged by the CNS CRB. The RCSF is helping us with the advertising and the venue.

Special Events:

On December 13th, 2011, the CNS-Chalk River Branch and the NA-YGN Chalk River chapter co-organized the first social mixer/mentorship opportunity. Our speakers included Bruce Wilkin, Jeremy Whitlock, Gina Strati, Bryan White, Mike Atfield and Dave Torgerson. A total of 16 attendees (age 22 to 35) were present. The event was opened only to CNS and/or NA-YGN members.

Jeremy Whitlock gave a 15 min presentation on the history of nuclear and what the new generation should do to continue the progress in the field. All other speakers introduced themselves, briefly talked about some of their work, and presented some of the lessons they've learned throughout their careers. The event was very well perceived by both the speakers and the attendees, and we were asked for a follow up at least once every quarter.

CNS President Frank Doyle (3rd from right) spoke at a dinner meeting of the Chalk River Branch. With him are: L to R: Shaun Cotnam; Bryan White; Ruxandra Dranga (Branch Chair); Frank; Bruce Wilkin; Natalie Sachar.

On February 21, the Branch held its 7th President's Dinner at which CNS President Frank Doyle spoke on "The future of nuclear in Canada and the roles of CNS, COG and the Chalk River Laboratories.

GOLDEN Horseshoe - Kurt Stoll

On January 13, Dr. T. (Nithy) Nitheanandan, Manager of Fuel & Fuel Channel Safety Branch at Chalk River Laboratories, and Chair of the COG Fuel & Fuel Channel Working Group gave a presentation at the McMaster campus about the experiments he has been involved with. Most were CANDU safety experiments and were motivated by CNSC generic action items. The entire McMaster engineering physics (nuclear) graduate student population attended and all were impressed with the scale of the experiments discussed. Dr.Nitheanandan's presentation is noteworthy for not only its depth of technical quality but also for its videos which depict thermalhydraulic experiments driven to their destructive limit.

On January 25 Dr. Victor Snell, Program Director, University Network of Excellence in Nuclear Engineering, Owner VGSSolutions (consulting in nuclear licensing, safety and education) and Former Director of Safety and Licensing at Atomic Energy of Canada Ltd, gave a presentation to 80 attendees regarding the basic operation and safety of CANDU reactors. The event was held at the Burlington Art Centre. The majority of the attendees were senior-level engineers from outside the nuclear industry who were interested in learning more about CANDU reactors and the nuclear industry. Because the audience consisted of established technicians, the questions which followed the presentation were excellent and went so long we had to cut the questioning short. This event was co-hosted by the CNS Golden Horseshoe Branch and the Burlington/Hamilton PEO Chapter.

OTTAWA – Mike Taylor

In January, branch members heard an interesting and informative talk by Cedric Jobe, of the Ontario Ministry of Energy, Cedric travelled from Toronto to tell us about Ontario Energy Policy, with particular reference to nuclear power.

On February 13 the Branch held a dinner meeting at which Norm Sawyer, Executive Vice President and Chief Nuclear Officer at Bruce A spoke about Bruce A's history, the Restart of Units 1 and 2, the continued safe operation of Units 3 and 4 and the future of Bruce Power. Close to 40 members and guests attended.

Also in February members of the Branch were involved in a local science teachers' PD Day, a talk to a local grade 8 class on nuclear energy and assisting with the CNS stand at the CNA conference.

PICKERING – Leon Simeon

There are currently 36 regular members and 2 retirees listed. We had 2 new members join the CNS in the last month and will be recruiting more this year.

Recent Activities, Presentations and Meetings

Met with Pierre Tremblay – Chief Nuclear Operating Officer at OPG -to solicit his support for the 2012 activities that are planned for 2012 in Pickering. Pierre supports the initiatives that are planned and is on board to be a future guest speaker.

A lunch and learn session was held on January 26th at the Pickering Learning Centre. The topic presented was "*Using Neurofeedback for Improving Nuclear Operator Performance*". The guest speaker was Rob Templeton from OPG Nuclear Oversight department and he provided the members with insights into how this technology can be used to improve nuclear operators' performance. Frank Doyle, President of the CNS also provided the group with highlights of upcoming CNS events and the goals of the CNS.

Pickering branch members were also provided with the opportunity to attend a CNS UOIT presentation by Dr. Peter Berg on January 23rd. The topic presented was *"Why Not Nuclear? And Why!"* The Pickering branch also got the opportunity to meet the new executives of the UOIT branch.

A lunch and learn session was held February, 24th at 777 Brock Road in Pickering. The topic was "Outage Optimization Project at Wolsong, Qinshan, Cernavoda, Point Lepreau, Darlington and Pickering"

A scholarship has been established at the Pickering High School for a graduating student with excellent academic standing in science and knowledge of nuclear science and technology.

UOIT – Terry Price

In late January the Canadian Nuclear Society Branch at UOIT held an election for the Branch executive, with the following results:

Branch Chair	Terry J Price
Vice Chair	Ronny Chiu
Secretary	Nivedita Menon
Treasurers	Calvin Ismail, Cora Wong
Operations	Miral Chaun
Members-At- Large	Adam Caly, Ricardo Rosie, Kale Staleart, Jim Demarker, Brad Rawlings, Jordan Tanner, Eugene Saltanov, Mike Aderly, Mike Gilbert, Ray Mutiger

As of the middle of February the UOIT CNS Branch has 133 members. This is a 46% increase over last year. The mailing list has 196 subscribers - a 180% increase from last year. The events planning meetings now regularly draw 15 to 20 members.

Obituary

Charles Howard Millar

Charles (Chas) Millar, a pioneer at the Chalk River Laboratories, died December 28, 2011 at the age of 91.

Chas was born in Waterloo, Quebec and grew up in Montreal. He obtained a B.Sc. at Bishop's University in 1940 and an MA in physics from the University of Western Ontario in 1942. He immediately joined the National Research Council in Ottawa working on radar.

When the Second World War ended he went to McGill University to study the new subject of nuclear physics, obtaining a Ph.D. in 1947. That led him to the Chalk River Nuclear Laboratories, then managed by the NRC, where he joined the nuclear physics division. (CRNL was taken over by Atomic Energy of Canada Limited when that company was created in 1952.) A decade later he transferred to the reactor physics division and was very involved with the ZED-2 low power research reactor (which celebrated its 50th anniversary in 2010).

In the early 1960s, he took a two year assignment with the NORA project in Norway, accompanied by his wife Ruth and three daughters.

After returning to Chalk River, Chas subsequently was appointed head of the Advanced Projects and Reactor Physics Division.

He retired from AECL in 1975 and the following year accepted the position of Director of Nuclear Safety and Environmental Protection at the International Atomic Energy Agency in Vienna, Austria. At the end of that four-year posting he and his wife returned to Deep River.

Over the years Chas was very involved with the community, being on the first Council when Deep River became a town, and a member of the hospital board. He was also an active naturalist concentrating on skiing in the winter and canoeing and sailing in the summer. In 1967, for Canada's centennial, he and two daughters canoed from Deep River to Ottawa.

He was predeceased by his wife in 2005.

Correction Notice

In the History article "Microwatts to Megawatts" by James Arsenault, which appeared in the December 2011 edition of the Bulletin (page 35), references were made to Irene Joliot-Curie and Frederic Joliot-Curie. The name Joliot was spelled "Joliet" in some places. The correct spelling is **Joliot**.

Canadian Nuclear Society
24th Nuclear Simulation Symposium
PROGRESS IN SIMULATION TOOLS AND METHODS

2012 October 14-16
Ottawa Marriott Hotel
Ottawa, Ontario, Canada

Call for papers

Photo taken at Ottawa October 14, 2006 (© zen! / Flickr)

The Canadian Nuclear Society is organizing its 24thNuclear Simulation Symposium. The symposium will be held in Ottawa (Ontario, Canada) from October 14 to 16, 2012.

Objective
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.

Topics of interest
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

Guidelines for full papers
The papers should present facts that are new and significant or represent a state-of-the-art review. A clear exposition of the subject should be made in approximately 10 pages.Proper references should be included for all closely related published information.

Submission procedure
Submissions of full papers, preferably in MS Word format, must be made electronically through the symposium submission site:
https://www.softconf.com/c/CNS2012Simulation/

Important dates
Deadline for full papers submission: .... May 31, 2012
Notification of acceptance: ....June 30, 2012
Deadline for final papers submission: ....August 15, 2012
End of early bird registration: .... August 31, 2012

Symposium registration fees (HST included)
By August 31 / After August 31
CNS Member: .... $570/$640
Non CNS Member: ....$670 / $740
CNS Retiree Member: ....$200 / $240
Full-Time Student: ....$200 / $240

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2012

Mar. 18-23 — **18th Pacific Basin Nuclear Conference**
Busan, Korea
website: www.nuclear.or.kr or www.kaif.or.kr/eng

Mar. 19-22 — **2nd International Nuclear and Renewable Energy Conference**
Amman, Jordon
Paper submission
email: rizwan@illinois.edu
copy to: secretariat@inrec-conf.org

Apr. 16-May 4 — **Seminar and Training to Transfer Knowledge in Scaling Uncertainty and 3D Coupled Code Calculations**
Daejon, Korea
website: www.grnspg.in.unipi.it/3dsuncop

Apr. 15-20 — **International Topical Meeting on Advances in Reactor Physics (PHYSOR 2012)**
Knoxville, Tennessee
website: www.physor2012.org

Apr. 18-20 — **3rd China-Canada Joint Workshop on Supercritical Water-cooled Reactors**
Xi'an, shaanxci, China
email: junligou@mail.xjtu.edu.cn

June 10-13 — **33rd CNS Conference and 36th CNS/CNA Student Conference**
Saskatoon, Saskatchewan
website: cns-snc.ca
email: cns-snc@on.aibn.com

June 24-28 — **ANS Annual Meeting**
Chicago, Illinois
website: www.ans.org

July 30-Aug. 3 — **ICONE 20 and ASME Power**
Anaheim, California
website: www.asmeconferences.org/ICONE20Power2012

Sept. 9-13 — **9th International Topical Meeting on Nuclear Thermal Hydraulics, Operation and Safety (NUTHOS)**
Kaohsiung, Taiwan
website: www.NUTHOS-9.org

Sept. 19-21 — **CNS Fuel Technology Course**
(location to be determined)
email: csn-snc@on.aibn.com
website: www.cns-snc.ca

Sept. 24-28 — **Nuclear Plant Chemistry Conference NPC 2012**
Paris, France
email: jean-luc.bretelle@edf.fr

Oct. 14-16 — **24th Nuclear Simulation Symposium**
Ottawa, Ontario
Contact: CNS Office
email: cns-snc@on.aibn.com
website: www.cns-snc.ca

Nov. 11-14 — **7th International Conference on Steam Generators, Heat Exchangers, Pumps, Valves and Controls (SCG 2012)**
Toronto, Ontario
Contact CNS office
email: cns-snc@on.aibn.com
website: www.cns-snc.ca

Nov. 11-14 — **ANS Winter Meeting and Nuclear Expo**
San Diego, California
website: www.ans.org

2013

May 12-17 — **15th International Topical Meeting on Nuclear Reactor Thermal Hydraulics (NURETH 15)**
Pisa, Italy
email: dlshubring@ufl.edu

May 27-29 — **3rd Climate Change Technology Conference**
Concordia University, Montréal, Québec
(Organized by EIC including CNS)
website: www.cctc2013.ca

Agreement with Italy on the Import and Export of Radioactive Sources

The Canadian Nuclear Safety Commission (CNSC) has signed an administrative arrangement with the Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA) of Italy to harmonize regulatory controls on the import and export of radioactive sources.

Administrative arrangements establish measures to ensure that imports and exports of Category 1 and 2 radioactive sources between Canada and its bilateral partners are conducted in a manner consistent with requirements under the International Atomic Energy Agency's (IAEA) *Code of Conduct on the Safety and Security of Radioactive Sources* (PDF) (the Code) and the IAEA's *Guidance on the Import and Export of Radioactive Sources* (PDF) (the Guidance).

The signing of the administrative arrangement with ISPRA contributes to the efforts and commitments the organizations and their governments have made to the establishment of a harmonized international regime to ensure the safety and security of Category 1 and 2 radioactive sources.

Nifty at Fifty

by Jeremy Whitlock

Hello old-timer.

What are you talking about, "old-timer", I'm only turning fifty.

Really? Canadian Nuclear Power is only fifty? But...

But I look much older right? Hey it's been a long fifty years.

I was going to say you've achieved so much, I thought you were older.

Yeah, pull the other one skippy.

No really - you're a legend. You were the first power reactor to refuel on-line, the first to use natural uranium and heavy water, the first to use computer control... You run half the province of Ontario, you've generated over a hundred million megawatt-days of electricity in Canada and avoided over 20 million tonnes of air pollution, over two billion tonnes of CO2...

My back hurts.

Honestly, we should be celebrating you more. Fifty years eh? You're like a Canadian icon: the Avro Arrow that the Tories didn't destroy.

Not yet anyway.

You should be on a stamp. You've saved over 20,000 lives from lung disease. You add over $6 billion to the GDP each year. I mean, you should at least be up there with everything else celebrating fifty years in 2012.

Like?

Like the Canadian Coast Guard! Or the Canadian Wildlife Federation! Or the Queen's reign! Or the Beach Boys! Or medicare!

They're all fifty this year? That's pretty good company I guess. I like the Beach Boys.

And you're responsible for just as much "good vibrations" over the years, my friend.

And some "bad vibrations" too. You recall the impeller problem at Darlington in the early 90s?

I sense you have some self-image problems. You know what I think? I think you haven't had enough people hug you.

Keep away from me.

Fair enough. Listen, how are things going?

I told you. My back hurts.

Yes, besides that. How do you feel about turning 50?

Well, to be honest I don't know where the time has gone. It just seems like yesterday we were on that bluff over the Ottawa River in Rolphton, doing stuff that nobody's done before.

Like on-line refuelling?

No, like standing on a bluff over the Ottawa River in Rolphton.

Oh, um...

Yes, of course on-line refuelling, and making electricity from uranium without needing a weapons program to make the fuel.

See? That's the spirit.

And we designed that reactor to change out pressure tubes as needed – imagine: built-in system aging management in an intensely radioactive environment.

There you go. Technology built on NRX and NRU experience, and still setting CANDU apart today right?

And we tested thorium fuel in that reactor on the bluff over the Ottawa River, can you imagine that? People are just thinking now, in the 21st century, that that might be a good idea.

Probably didn't even seem like being innovative right? Just seemed like a good idea at the time?

And talk about a Small Modular Reactor! 22 megawatts: just the right size for the job, scaled up in the decades to come as the market required.

So here you are. And turning fifty isn't so bad right?

Well, you know, it's just that you get tired of the aches and pains, the poking and prodding. Back in the day my pipes were clean, my chemistry was tracking closer to spec, and hardly anything was leaking...

Big plans ahead? Prime of your life...?

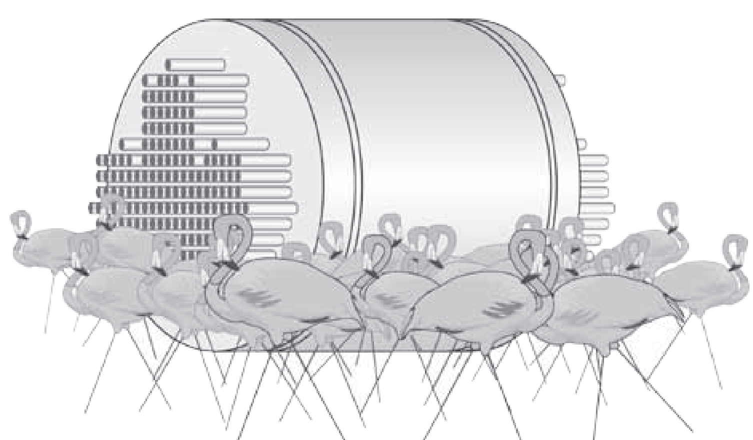
Ah, that's where the irony sets in. I'm fifty years old and the biggest plans I have are to do the same thing I did fifty years ago: in 2012 it's almost as unusual to build a nuclear power reactor in Canada as it was in 1962. In fact in some ways it's even more unusual.

How so?

Well these days it seems to be all about the windmills, the solar panels – the "feed-in" ransom paid to ideology, while natural gas is burned to take up the slack. I've got a boil on my bum that can do it more efficiently and greener than all of that noise combined. The most sustainable way to make electricity today in Canada was pioneered on a bluff over the Ottawa River in Rolphton in 1962.

Anyway, thankfully you didn't bring up early retirement...

Show me the package, skippy.



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