CANADIAN NUCLEAR SOCIETY
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• Fire Safety and Emergency Preparedness • Meet the new CNS President • History: Archives of Dr George C. Laurence

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Emergency Preparedness: A Work in Progress (Always!)

On November 11, 1979, I was driving my family along the QEW into Toronto to visit the King Tutankhamun Exhibit. We passed an ambulance speeding in the opposite direction through Oakville. We see that now and then. But it was soon followed by a second ambulance, then a third, then a fourth, and so on until I lost count ... I turned on the radio. There was no "all-news" station back then but on the hour (as we entered Toronto) the CBC spoke of an evacuation of the Mississauga hospital due to a train derailment with a potential for a toxic release. That was, of course, the "Mississauga Rail Disaster", occurring late the night before. Over the next few days some 200,000 people were systematically evacuated, the largest evacuation ever at the time. Notifications were mostly "door-to-door" visits.

The 106 car train contained toxic and explosive materials (including styrene, toluene, propane, caustic soda, and chlorine) and there was no separation of the cars according to their hazards. Explosive materials caught fire and threatened the integrity of adjacent cars containing chlorine. The cause of the derailment was a combination of poor maintenance and faulty equipment - an improperly lubricated journal bearing over-heated and the bogie broke apart. Newer cars at the time used roller bearings, but the old deficient ones were still in use. Several technical recommendations were made to reduce the risk of transporting dangerous goods, and the disaster resulted in improvements to emergency preparedness, particularly coordination, communication and clearer responsibilities among organizations.

Although the evacuation of Mississauga was orderly and without panic, despite the "real and present danger", that was not the case earlier that year when the accident at Three Mile Island led to panic and a highly chaotic evacuation, despite the lack of "real and present danger". Facts and perceptions were contradictory then (and still are!). Communities quickly rewrote their emergency plans.

Chernobyl was a different beast; the danger was very real and present, but the Soviet authorities were not prepared for an effective emergency response, nor were the Canadian authorities prepared when contaminated fallout fell on Canadian Soil. This prompted the Government of Ontario to expand its emergency preparedness role with a new Nuclear Emergency Plan that clarified responsibilities.

The former Ontario Hydro had been conducting nuclear emergency exercises but they did not always go well. For example, a dispute arose during a simulated accident as to who had authority to erect road blocks, not to mention evacuations (who gives the order, should they be mandatory, where should people go, what if they are contaminated, should dairy farmers dump their milk and on and on). There was, of course significant learning from these emergency exercises that always resulted in better inter-organizational coordination and communication.

Even at Fukushima there was inadequate communication and coordination; but in addition there was added confusion regarding "safe" or "unsafe" radiation levels that ended with poor judgement (in retrospect) regarding evacuations. Global emergency preparedness has been improving ever since.

The recent 2nd CNS Conference on Fire Safety and Emergency Preparedness is reported in this Bulletin. The emphasis was on the role of different government agencies for coordination and communication (always room for improvement), plant inspections and the province's clarification and simplification of evacuation criteria (hopefully this will avoid the confusion that occurred at TMI and Fukushima). On fire safety, the application of probabilistic risk analysis is now being used to identify significant hazards (welding, electrical, etc.). Fire safety compliance in a working site was discussed and problems were noted, such as blocked fire doors, blocked fire equipment, and incompatible activities near safety-sensitive equipment.

In short, we continue to learn from terrible events, not just historical but now predicted and simulated events, and we apply the learning to make improvements to our emergency preparedness. It will always be a work in progress, and that is a good thing!

In This Issue

The lead article is the 2nd Conference on Fire Safety and Emergency Preparedness, for which our cover photo and editorial seem appropriate.

In CNS News we have an interesting account and biography of our new president, Daniel Gammage. Despite his young 32 years of age he brings extensive experience and a refreshing drive to advance and improve the objectives and interest in the CNS. He has a broad range of professional expertise, primarily in nuclear plant components, and is also artistically talented (he sings and plays piano, trombone and tuba).

Congratulations go to Professor John Luxat, who was recently elected chair of the International Nuclear Energy Academy (INEA)! We also appreciate the efforts of the family of Dr. George Laurence in archiving his personal papers at the Library and Archives Canada. Thanks to James E. Arsenault for contributing this note of our history!

As colder weather approaches, there is no better time to relax beside your nuclear powered electric fireplace with a copy of *The Bulletin!*

From The Publisher

2017 is turning out to be an interesting year of ends and beginnings. This was clearly illustrated in September with the final end of the Cassini-Huygens mission on September 15 at 7:55 EDT. At that time, signal was lost when the Cassini space probe entered Saturn's atmosphere. The total elapsed mission time was 19 years, 11 months, 3 hours, 12 minutes and 46 seconds.

The final plunge to sample Saturn's atmosphere was the final action of Cassini which for nearly twenty years had served faithfully and reliably to provide an enormous amount of information about the solar system's second largest gas giant and its highly complex array of 53 moons. And its discoveries were indeed astonishing, with a number of Saturn's moons revealing that they possessed atmospheres, liquid water in large quantities and active geology.

Cassini was the largest and most complex unmanned space probe ever built by any space exploration program, and it was nuclear powered. Cassini used three RTGs (radioisotope thermo-electric generators) harnessing the decay heat of Plutonium 238 to provide power. And here we come to the first end and beginning. The antinuclear industry made spectacular fools of itself in its frantic attempts to block the mission before launch with its exaggerated claims about the hazards posed by its nuclear power system. Stated simply, space exploration beyond the orbit of Mars is utterly impossible because of lack of solar flux; nuclear power is the future of space travel and exploration.

And as a beginning, in February 2017, Ontario Power Generation entered into an agreement to produce new Plutonium 238 for future deep space missions. It will be produced at the Darlington nuclear power station. Very little of this plutonium oxide remained in inventory, barely enough for two more missions. This confirmed that Cassini will be far from the last such mission to come for our exploration and travel to distant bodies in our solar system. And these will have Canadian nuclear fuel powering them.

But Cassini was only one such end and beginning for nuclear power this year. Most of the nuclear power projects in the United States were canceled this year following the bankruptcy of Westinghouse. Despite that, nuclear power remains strong and growing in Canada and many other nations around the world. Seven companies and consortia have applied to the Canadian Nuclear Safety Commission (CNSC) for design approval of a variety of proposed small modular reactor designs. Canadian Nuclear Laboratories (CNL) received an astonishing 70 positive responses to its request for expressions of interest in SMRs. This in turn should mean that Chalk River may well have new life in the development of new reactor prototypes, a development not seen in Canada since the 1960s.

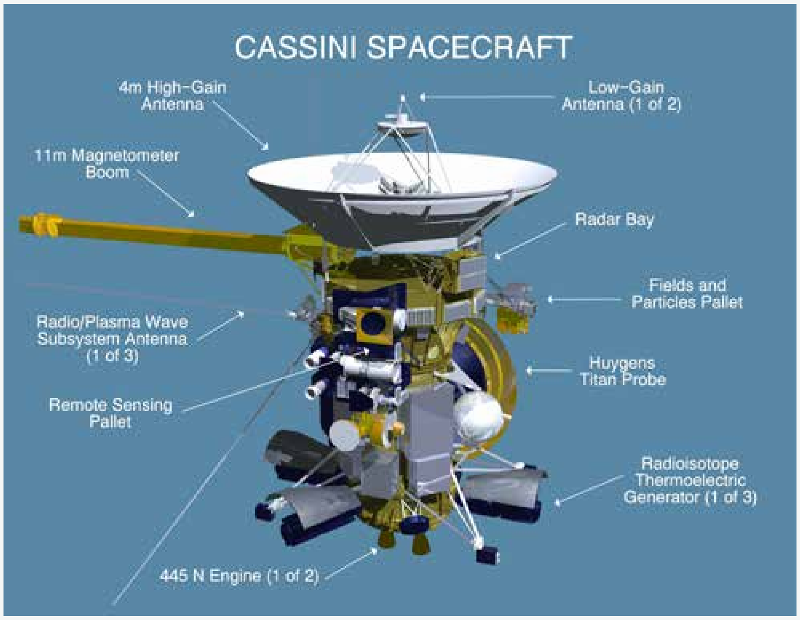
But that's not all for CNL. This year it opened the new Harriet Brooks Laboratory, the first very large new investment in nuclear research facilities at Chalk River in decades. In total, the federal government will invest $10 billion over 10 years in infrastructure and research programs at Chalk River constituting a renewal of Canada's nuclear R&D program not seen since the early days of nuclear research half a century ago.

Throughout 2017, work has continued on Darlington Unit 2 refurbishment program, and Bruce Power has continued its preparation work for starting its major component replacement program in 2020. These refurbishment programs will mean new life for Ontario's nuclear power program, meaning that nuclear power will continue to dominate Ontario's electricity supply well past the 21st century mid-point.

There are signs of new life and vigour for the Canadian Nuclear Society (CNS) as well. Our conferences have been well attended and filled with exhibitors from both Canada and around the world. With more than $25 billion in refurbishment projects on the books and strong interest in new small reactor designs, Canada is clearly an important place to be for the future of new nuclear power development and application.

From Cassini to Canada to the CNS, our nuclear future is strong and promising.

CGH



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Being prepared for emergencies includes having proper equipment and conducting emergency exercises.

Photo courtesy of Bruce Power.

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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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Correction

In the June 2017 issue of The Bulletin, Gary Newman of Bruce Power was incorrectly identified. He is Chief Engineer and Vice President Engineering. The Bulletin regrets the error.

2nd International CNS Conference on Fire Safety and Emergency Preparedness

Conference CoChair Rudy Cronk

Stephanie Durand, Public Safety Canada

The 2nd International CNS Conference on Fire Safety and Emergency Preparedness in the Nuclear Industry kicked off in Toronto on Monday, September 18, 2017. More than 100 delegates were in attendance, along with over a dozen exhibitors.

The three-day conference commenced with a strong opening plenary session panel including Stephanie Durand, Director General, Public Safety Canada; Peter Elder, CNSC; David Nodwell, OFMEM; and Paul Serra of INPO. Opening the session, Ms. Durand outlined the role of PSC and its goals. Specifically, the role of PSC is to limit the impact of threats to public health and safety and to strengthen coordination among responsible agencies. She noted that the role of the federal government is not to supercede other agencies and department but to ensure communications and coordination among them. She outlined a number of recent activities by PSC:

- Conducted a post-Fukushima assessment;
- Launched a new $2 billion infrastructure fund for disaster relief;
- Worked with CRTC (Canadian Radio and Telecommunications Commission) to ensure that all wireless networks will carry public alerts;
- Commenced work on the need for a Canadian strategy for wild-fire management.

Following Ms. Durand, Peter Elder observed that in emergency planning the controls must be proportionate and appropriate for the risk posed by a potential threat. He also indicated that the enforcement philosophy of the CNSC was to use the minimum necessary coercion to achieve the desired response. The purpose of mechanisms for dealing with breaches of licence conditions was not to punish lapses but to ensure they were improved to meet requirements. He agreed with Ms. Durand that the objectives of the CNSC in emergency planning were achieved by coordination with a number of other government agencies.

David Nodwell outlined the roles and actions of the Ontario government in emergency planning. This is coordinated provincially through the Provincial Emergency Operations Centre by the Ontario Ministry of Community Safety and Correctional Services. He noted that the provincial emergency plan was updated in 2011 and will be updated again by the end of this year.

The revisions to the plan include a number of changes:

- Maintenance of the existing planning zones but

Honorary Conference Chair Frank Saunders

Paul Serra, INPO

Peter Elder CNSC

inclusion of a new category of Contingency Planning Zones;

- Use of a single value for determining evacuation. On the recommendation of Health Canada, this is set at an exposure of 50 mSv or greater over a seven-day period.

The final speaker of the opening plenary was Paul Serra of the Institute of Nuclear Power Operators (INPO). Mr. Serra described the nature and scale of its peer-review inspections out of its five global main offices in Atlanta, London, Paris, Moscow and Tokyo. INPO's inspections typically take one week on site, and they provide reports on performance or equipment errors, and why and how they were caused.

Tuesday's plenary session was essentially in two parts: Gary Yaskevitch of AECL reviewing recent developments of Canadian Nuclear Laboratories (CNL), and Kevin Daniels of CNL reporting on the recent surge of interest and activity in small modular reactors. In his remarks, Mr. Yaskevitch noted the changes in ownership of the CNL managing company, with SNC Lavalin taking over Adkins, and Jacobs taking over ch2M Hill.

Mr. Daniels noted that CNL had attracted 70 responses to their request for expressions of interest in small reactors. He indicated that there were two strong reasons for such interest: the high suitability of Chalk River for prototype development; and the efficient performance-based regulatory structure of the CNSC.

The second half of Tuesday's plenary was devoted to fire safety. Elizabeth Kleinsorg of Jensen Hughes spoke about the conduct and application of probabilistic risk analysis to fire safety. Luke Morrison of PLC noted the difficulties of fire safety compliance in a working site. These include examples such as blocked fire doors, blocked fire equipment, or incompatible activity near safety-sensitive equipment.

The concluding plenary on Wednesday started with Dr. Marina Rowekamp, GRS Germany, who outlines the results of the OECD fire data base. Thirteen countries including Canada provide data to the OECD. The results showed that transformers and electrical cabinets were the most vulnerable for risk of fires, while hot work welding or cutting provided most of the ignition sources.

Elizabeth Kleinsorg, Jensen Hughes

The final plenary of the conference included the most fascinating presentation of all, a review by Dominic Harrison, head of Sellafield Fire and Rescue of the complexity of ensuring safety performance at this old and highly complex site.

The Conference was sponsored by Jensen-Hughes, Bruce Power, PLC Fire Safety Solutions, Callian, and the Canadian Nuclear Safety Commision (CNSC). Exhibitors included Ares Security, Areva, Atkins, Bruce Power, Canadian Nuclear Laboratories, Jensen Hughes, EPM Engineering, KLD Engineering, NA Engineering Associates Inc., Nuvia Canada, Pixeltek, PLC Fire Safety Solutions, Troy Life & Fire Ltd., and Victaulic.

Shahina Kurien and CNS President Dan Gammage close the conference.

This second international conference on fire safety and emergency preparedness conference follows on the first time the CNS first ran this conference in 2015. The first conference was very much an exploratory venture into this topic with a primarily Canadian audience and exhibitors.

This year's conference drew a much wider range of participants. The technical topics included a much larger focus on site fire safety analysis. It also included a much larger participation from civic fire safety departments whose communities contain Canadian nuclear facilities. Finally, it included a large number of participants, exhibitors and sponsors from the United States, making this conference have a much larger international flavour.

What the conference also showed was that a much wider range of tools and techniques exist now for analyzing fire safety and emergency risks than existed one or two decades ago. The technical presentations from Canada's nuclear facilities operators showed that the lessons from the 2011 Fukushima accident have been incorporated into site planning, safety and operations.

Real Costs of Electricity in Ontario

by SCOTT LUFT

Author: Cold Air: Analysis and commentary on energy, environment, and politics

This week I was handed some data indicating, by supply type, electricity generation and costs in Ontario. The data was a hard copy response of the IESO to a freedom of information request. There's nothing in the data that will surprise readers of my work, but perhaps it's time for a refresher, as today I read one flip comment by a mainstream journalist, joking they'd like to see "Ontario families can no longer afford sky-rocketing nuke costs," and an opinion piece on the public broadcaster›s site which included:

> *...as data from the [International] Electricity System Operator clearly shows (sic), it's nuclear and gas plants that are responsible for the lion's share of increases.*

"Clearly."

It is time for a refresher.

Figure 5: Breakdown of Generation Cost By Energy Sources, 2014

Source of data: Independent Electricity System Operator

Technology	Cost ($ million)	Total Production (TWh)
Nuclear	5,900	**94.9**
Hydro	1,835	**37.9**
Gas/Oil	2,287	**14.9**
Wind	935	**7.8**
Solar	884	**1.8**
Bioenergy	100	**0.5**
Coal	7	**0.1**
Other*	186	**1.6**
Imports	251	**4.9**
Export (Revenue)	(636)	**(19.1)**
Total Generation Cost	**11,749**	

Some background on the data I'll share. The 2015 Annual Report from the office of The Auditor General of Ontario included a chapter on "Electricity Power System Planning." The entire chapter contained a wealth of information and continues to be cited frequently, but for those chasing hard numbers one particular star of the work was a figure revealing the quantity, and cost, of generation from various sources, inclusive of not only the larger generators frequently reported by the IESO (the "I" is not for international, but it is the electricity system operator), but also the seldom reported distributed generation - which is where most solar exists.

The freedom-of-information requests handed to me included this request: *Breakdown of Generation Cost by Energy Sources for the years 2007, 2008, 2009, 2010, 2011, 2012, 2013 and 2015. The Breakdown for 2014, which was included in the Annual Report of the Auditor General of Ontario, is attached as reference.*

The data table that follows responds fully with the request - I have only reformatted it:

These are numbers honest people might agree on as a basis for arguments. I'll note in January 2016 I estimated figures for 2015 in Beyond expectedly high cost: 2015 Ontario Electricity Summary Part 3 - and these new figures don›t change anything I wrote back then. But there are some points to re-emphasize based on the trend from 2007-2015.

One immediate point is the many possible sane data-based claims do not include the, *"nuclear and gas plants that are responsible for the lion's share of increases,"* published on the public broadcaster's site.

Nuclear does have the greatest dollar increase from 2007-2015, but it also has the highest growth in generation. The increase in solar is 77% of nuclear's increase, and the increased cost of wind is 70% nuclear's increase - so the combined impact is nearly 50% greater. The increased cost of generation from natural gas suppliers has risen less than either.

Some costs have declined: coal and imports.

I caution on performing complex calculations for coal, gas/oil, bioenergy and other categories. The primary reason is the notation that "other" includes "contingency support payments", which are significantly comprised of payments to keep coal generators in service (and perhaps oil and gas fueled Lennox). This grouping contains the benefits of the cost reductions from eliminating coal benefiting gas - but there's a good case to be made that most of the capacity built specifically to replace coal's reliability attributes was gas-fired.

The instinct among most people is to calculate a rate per unit (I'll use dollars per megawatt-hour) to

Breakdown of Generation Cost by Energy Sources for years 2007 to 2015									
Cost $M (Nominal)									
Fuel Type	2007	2008	2009	2010	2011	2012	2013	2014	2015
Nuclear	$4,072	$4,389	$4,725	$4,542	$4,843	$4,729	$5,618	$5,900	$5,864
Hydro	$1,441	$1,700	$1,426	$1,339	$1,385	$1,260	$1,575	$1,835	$2,159
Coal	$1,505	$1,332	$415	$552	$152	$128	$106	$7	
Gas/Oil	$1,147	$1,244	$1,511	$2,152	$2,231	$2,191	$2,480	$2,287	$2,183
Wind	$87	$128	$194	$272	$435	$556	$661	$935	$1,346
Solar				$49	$197	$428	$597	$884	$1,386
Bioenergy	$88	$76	$66	$93	$95	$93	$98	$100	$194
Other	$108	$125	$69	$358	$452	$429	$387	$191	$60
Imports	$378	$636	$167	$243	$140	$132	$144	$251	$169
Export (Revenue)	-$594	-$1,212	-$500	-$567	-$419	-$364	-$507	-$636	-$606
Total Domestic Generation Cost	$8,232	$8,419	$8,073	$9,033	$9,512	$9,581	$11,160	$11,753	$12,753

TWh									
Fuel Type	2007	2008	2009	2010	2011	2012	2013	2014	2015
Nuclear	80.8	84.4	82.5	83.3	85.9	85.6	91.1	94.9	92.3
Hydro	33.0	37.7	37.8	31.6	34.5	33.6	36.7	37.9	37.2
Coal	28.4	23.1	9.7	12.5	4.0	4.3	3.1	0.1	
Gas/Oil	12.2	11.0	15.3	19.9	21.5	22.3	17.3	14.9	15.5
Wind	1.1	1.5	2.5	3.1	4.4	5.3	6.1	7.8	10.2
Solar				0.1	0.4	0.8	1.2	1.8	3.0
Bioenergy	1.3	1.0	1.3	1.3	1.2	1.3	1.5	0.5	0.6
Other	0.6	0.7	0.6	0.2	1.0	0.8	1.9	1.6	1.4
Imports	7.2	11.3	4.8	6.4	3.9	4.7	4.9	4.9	5.8
Export (Revenue)	-12.0	-22.0	-15.0	-15.0	-13.0	-15.0	-18.0	-19.0	-23.0
Total Energy Production	152.2	148.6	139.4	143.2	144.1	144.0	145.5	145.3	143.2

Other Includes IEI, electricity via storage production, funds, interest, liquidated damages, contingency support payments and etc.

compare sources. I have done so, and additionally calculated the average annual increase, in rates over the 8 years. While stressing these calculations deserve a big asterisk and lengthy footnote on the impacts of things such as curtailment and capacity payments, the simple figures provide an interesting context for contemporary stories on the province's electricity sector.

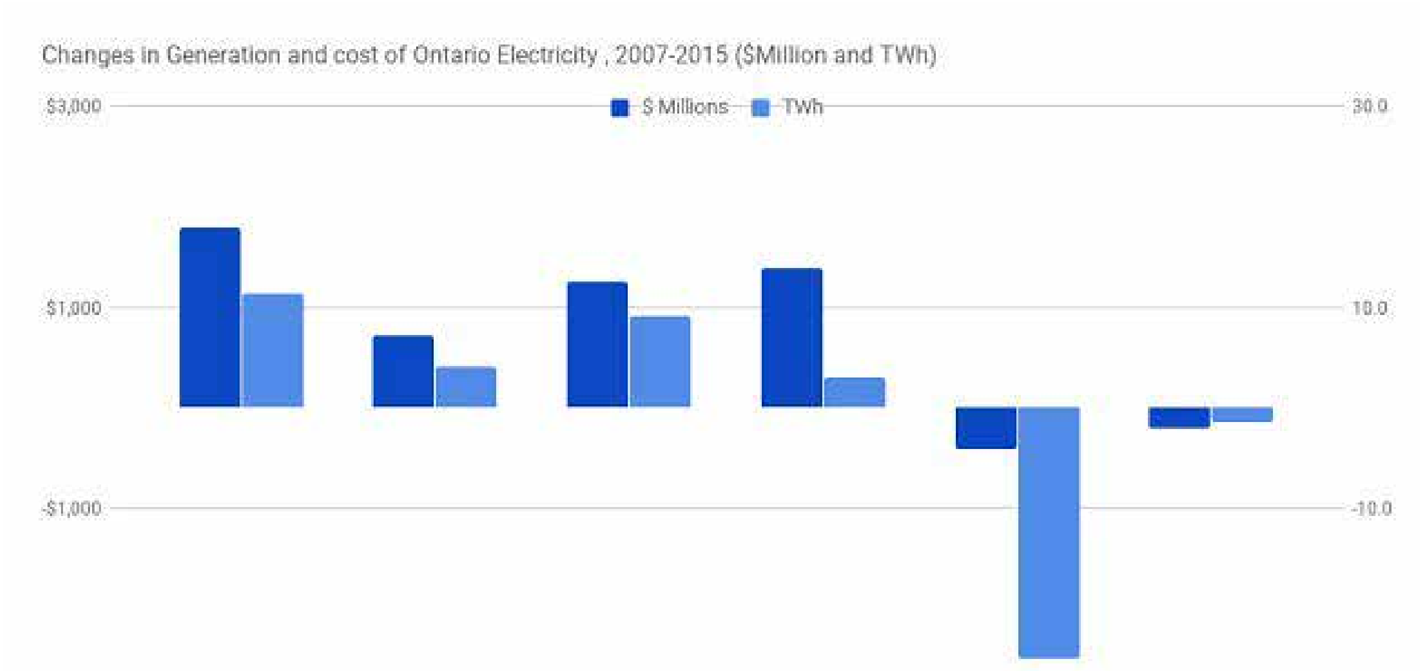
The only source of generation with a declining average cost per unit is imports. Unburdened by contracting this is one source that hasn't seen increasing generation. The government's recent actions in contracting from Quebec a fixed quantity of supply, at a fixed rate, is the opposite of data-driven policy.

Another curiousity from looking at rates: nuclear increased at under 3% a year, while wind increased at over 6%. There is lots of room for interpretation, but no room for claiming increasing rates for nuclear supply, not renewables, have driven the large price increases of the past decade.

Many might be surprised by the increased average unit cost of wind - although not those that read The diminishing value, and increasing costs, of wind and solar generation in Ontario on this site over 4 years ago. To explore the increase in wind cost a little further, let me first introduce data for 2016.

The Ontario Energy Board recently released 2016 "System-Wide Electricity Supply Mix" data. I've used this data in the past to estimate annual generation (including distribution-connected resources) and the new information from the FOI documentation shows those estimates were very close. Adding 2016 data to my existing work shows the following generation levels:

I've estimated 2016 wind costs by adding the value of reported hourly wind generation at the Hourly Ontario Energy Price ($119.5 millions) to the wind portion of



Rate ($/MWh)										Average Annual Increase
Fuel Type	2007	2008	2009	2010	2011	2012	2013	2014	2015	
Nuclear	$50	$52	$57	$55	$56	$55	$62	$62	$64	2.9%
Hydro	$44	$45	$38	$42	$40	$38	$43	$48	$58	3.6%
Wind	$83	$86	$78	$87	$98	$105	$109	$120	$133	6.1%
Solar				$408	$518	$522	$515	$491	$460	2.4%
All Others	$67	$78	$77	$93	$106	$99	$129	$151	$139	9.6%
Imports	$52	$56	$35	$38	$36	$28	$29	$51	$29	-7.0%
Export (Revenue)	$50	$55	$33	$38	$32	$24	$28	$33	$26	-7.6%
Total Energy Production	$54	$57	$58	$63	$66	$67	$77	$81	$89	6.4%

OEB Ontario's Electricity Mix*					terawatt-hour estimate			
Electricity sources	2013	2014	2015	2016	2013	2014	2015	2016
Water power	23.4%	24.1%	23.2%	23.3%	36.8	38.1	37.0	36.5
Solar	0.8%	1.1%	1.9%	2.2%	1.3	1.7	3.0	3.4
Wind	3.9%	4.9%	6.4%	6.8%	6.1	7.8	10.2	10.7
Biomass***	1.0%	1.0%	0.4%	0.5%	1.6	1.6	0.6	0.8
Waste^	0.1%	0.1%	0.0%	0.0%	0.2	0.2	-	-
Nuclear Energy	57.9%	60.0%	57.8%	58.5%	91.1	94.9	92.3	91.7
Natural Gas**	10.9%	8.7%	9.7%	8.2%	17.2	13.8	15.5	12.9
Other (includes coal)	2.0%	0.1%	0.6%	0.4%	3.1	0.2	1.0	0.6
total					*157.3*	*158.2*	*159.7*	*156.6*

the global adjustment ($1.552 billion). Appending the 2016 calculations to the revealed 2007-2015 figures shows the expected result of a decrease in average value accompanied by an increase in average cost.

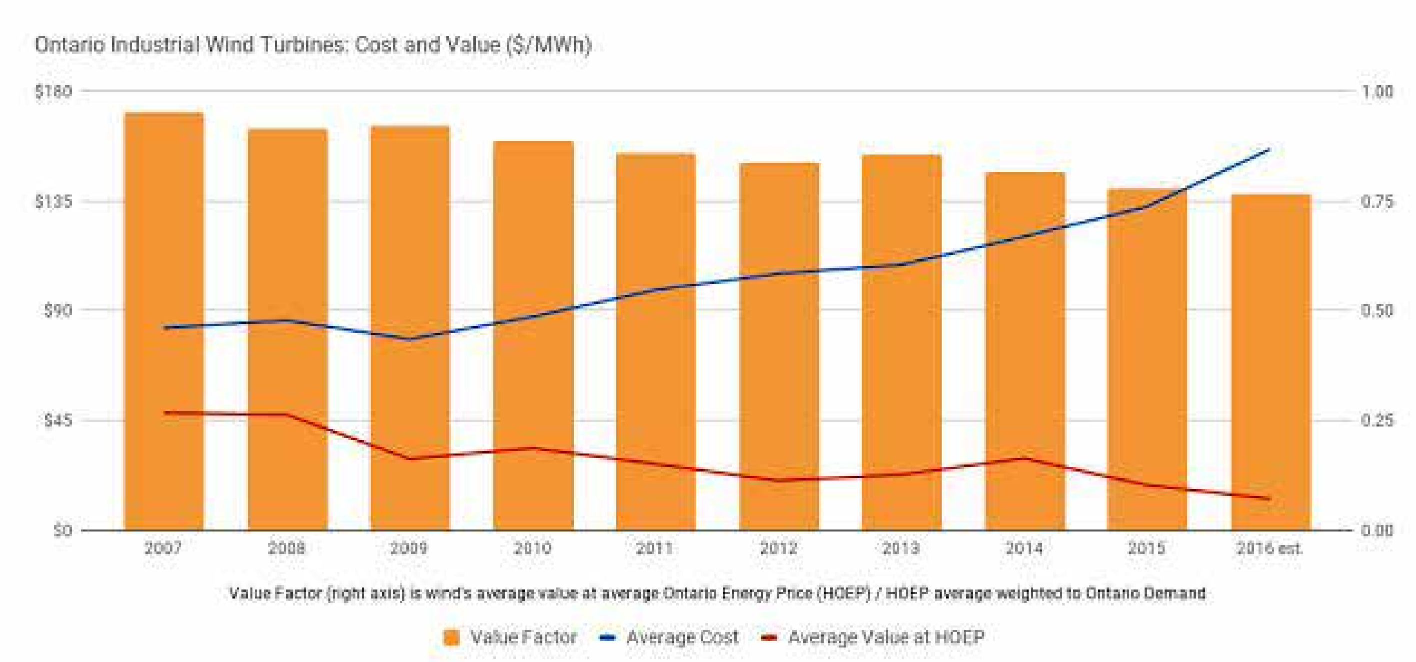
The future of Ontario's electricity supply is not as clear as it was when I started writing this blog nearing 7 years ago. It could be an exciting time as Ontario has minimal emissions during a period many jurisdictions claim to want low emissions - but it's hard to see how the general quality of conversation can improve when the mainstream media continues to muddle the basic facts.

Note: A big reason basic facts are muddled is the growth in distributed generation - which the IESO does not report on. Sensitive to the issue, I noted the following in the IESO's reporting on their handling of the recent solar eclipse:

Prior to the beginning of the event, output of embedded solar generation, that is generation connected within Ontario's local distribution systems, was approximately 1,470 megawatts (MW)...

At the peak of the eclipse...solar generation output was reduced ...to approximately 490 MW for embedded solar generation...

By the end of the eclipse at 3:50 p.m. EDT, embed-



ded solar generation had recovered to approximately 1,250 MW

If the IESO is tracking embedded solar generation, why do they have no meaningful reporting of it's hourly output?

Letter to The Editor

Dear Editor;

The industry move to develop SMRs makes a lot of sense when one considers the application to remote Canadian communities. Making technical, environmental and economic sense, however, does not automatically guarantee acceptance by those communities. Back in the early 1980s, the concept of a deep geological repository for used CANDU fuel made a lot of sense, too, but the perceived lack of effort to gain public acceptance delayed progress by several decades. Today, after fifteen years, the Nuclear Waste Management Organisation has gained world-wide acclaim for its program of public engagement in the search for a site for a repository. Even so, the search is not over – although the number of possible host communities is steadily narrowing.

As was the case with a waste repository, it will not do to approach the public with a ready-made nuclear solution to energy needs with no prior engagement. Opposition will inevitably be marshalled against distributed SMRs even as it continues to be marshalled against plans for waste disposal. SMRs are years away from realization; nevertheless, I would urge the industry take a leaf out of NWMO's book and develop a strategy for consulting the public, especially prospective host communities and their neighbours, sooner rather than later.

Yours sincerely,

Derek Lister
Professor Emeritus and Research Chair in Nuclear Engineering
Department of Chemical Engineering
University of New Brunswick
Fredericton, NB

Papers of Dr. George C. Laurence Deposited at Library and Archives Canada

Contributed by: JAMES E. ARSENAULT, P.Eng.

On 14 June 2017 the personal papers of Dr. George C. Laurence (1905-1987) were deposited at Library and Archives Canada (LAC). The papers had been located at the Laurence home in Deep River, Ontario, and were donated by Patricia (daughter of George) and Stuart Buchanan.

Patricia and Stuart Buchanan at Deep River with the Laurence Collection.

Dr. Laurence was one of Canada's prominent nuclear pioneers, beginning with alpha particle studies at Dalhousie (M.Sc. 1927), which he continued at the Cavendish Laboratory, Cambridge (Ph.D. 1931) under Rutherford. He joined the National Research Council (NRC) in 1930, conducting radiation standards work, and developed radiographic inspection techniques. In 1940 he nearly single-handedly designed and built the world's first uranium/carbon pile but it was not self-sustainable due to material impurities. At one point he was neck and neck with Enrico Fermi who eventually succeeded in building the first sustainable pile in 1942.

Dr. George C. Laurence, 1905-1987

In 1942 Dr, Laurence was assigned to the Montreal Laboratory, where he worked on various reactor designs including ZEEP and NRX. He transferred to Atomic Energy of Canada Limited (AECL) in 1952, the same year as the NRX accident, and became interested in reactor safety. He developed the early quantitative approaches to safety and the idea of independent layered systems. In 1961 he became head of the Atomic Energy Control Board (AECB), from which he retired in 1970. In retirement he was an advocate for the use of nuclear energy for the betterment of Canada and humanity in general. Throughout his long and productive career in nuclear science, he received many awards of recognition, including honorary degrees, medals, and certificates.

The initiative to archive his papers was formed shortly after the induction of Dr. Laurence into the Canadian Science and Engineering Hall of Fame in November 2010. Through the generous cooperation of the Buchanans, a preliminary survey was conducted and it was decided that a catalogue should be prepared for the extensive collection, comprising thousands of pages of text, and numerous photos and glass plates. Fortunately a library/archive standard was available, as a result of a Canadian Nuclear Society (CNS)/AECL project that had developed a catalogue of historical AECL reports (which has been posted to the CNS website). The Laurence catalogue was completed in the summer of 2016, by Lyn and Jim Arsenault, and the papers were organized into five banker's boxes. LAC agreed to take in the Laurence collection, which now resides safely alongside the NRC, AECL, AECB and Eldorado collections and, thus, is available to interested researchers.

Current Radiation Protection Limits: An Urgent Need for Change

Appropriate revisions to radiation protection guidelines for medical and nuclear power applications will ultimately lead to major public health and economic benefits.

by JERRY M. CUTTLER[1] and WILLIAM H. HANNUM[2]

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Following the February 24 signing of Executive Order 13777, "Enforcing the Regulatory Reform Agenda," by President Donald Trump, Environmental Protection Agency Administrator E. Scott Pruitt issued a memorandum to EPA staff on March 24. This led to the EPA's April 11 announcement that it was seeking in-put on regulations that may be appropriate for repeal, replacement, or modification. On April 13, the EPA published a notice in the *Federal Register* that established Docket ID EPA-HQ-OA-2017-0190 to re-ceive comments up until May 15. A total of 98,543 submissions were received as of May 20, with 31,378 results after filtering out those that did not meet the acceptance criteria. The authors provided comments on May 12 regarding the EPA's radiation protection regulations, as detailed in this article.

Current EPA regulations are based on the linear no-threshold (LNT) dose- response model. These regulations have long been considered to be conservative, and it is widely recognized that they are excessively restrictive. There is emerging evidence that the effects of low or even moderate levels of ionizing radiation are in fact beneficial. Researchers are now postu-lating that rather than being a simple cause of additional cell damage, the principal effect of low-level radiation is to stimulate the body's natural defense mechanisms—for instance, against cancer cells.

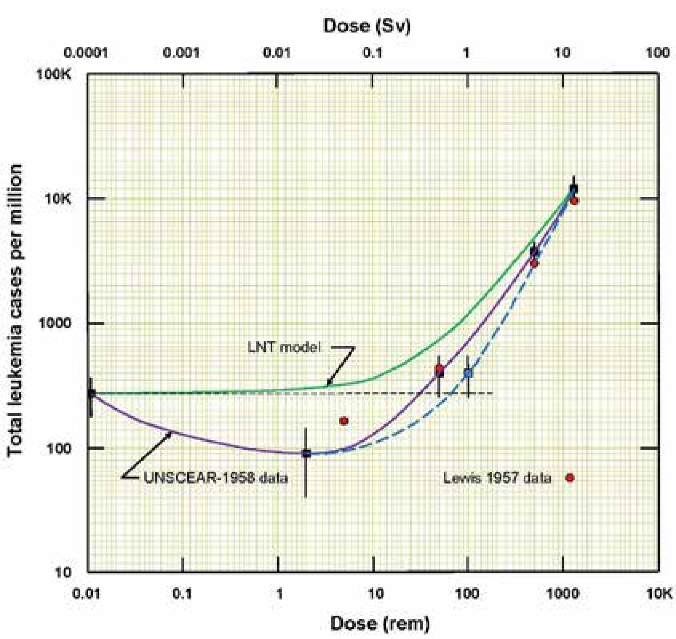

Fig. 1: Leukemia incidence from 1950 to 1957 among Hiroshima atomic bomb survivors.[1]

Many organisms receiving very high, but nonfatal, doses appear to have life ex-pectancies as great as those receiving only normal background radiation. Higher-than- normal background radiation does appear to increase longevity. Data from sources as diverse as Hiroshima survi-vors and beagle dog laboratory studies (conducted from the 1960s to the 1990s) are consistent in their conformance to a hormetic dose-response model, with sur-prisingly high thresholds for the transition between beneficial and harmful effects.

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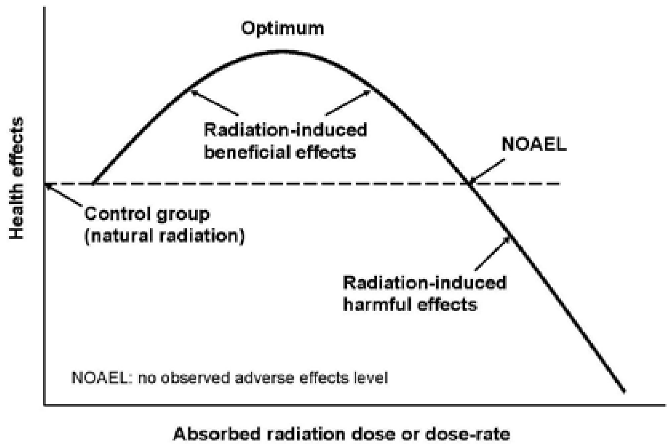

Fig. 2: Health effects caused by signals that are induced by radiation.

Confirmation and recognition of the potential benefits of low-level radiation will require a thorough review and revi-sion of radiation protection guidelines for both medical and nuclear power ap-plications. Appropriate revisions will lead to major public health and economic benefits.

Background

Most of us are frightened by the thought of being exposed to nuclear radiation. Very high doses kill within days to weeks, and survivors of acute radiation illness show an increased risk of cancer. While most of the casualties of the atomic bombs that were used in Japan to end World War II died from the blast or the heat, many received very high doses of ionizing radiation. Some died from organ failure and others died from cancer that developed years later. Many emergency workers re-sponded to the Chernobyl disaster, and 134 of them were heavily irradiated. Of these, 28 died within weeks, and 106 re-mained alive.

What about those who received high dos-es but survived? Since the most radiation- sensitive tissues are the blood-forming cells in bone marrow, leukemia is the can-cer most likely to occur among the Japa-nese atomic bomb survivors, beginning at about five years after exposure. Figure 1 shows that there was no excess leuke-mia incidence for Hiroshima survivors when the dose was below about 500 mSv (50 rem). This suggests that the thresh-olds for initiating other types of cancer or other health risks are likely higher than 500 mSv.[1]

Of the 106 heavily irradiated Chernobyl emergency workers who remained alive, 22 died over the next 19 years, a mortality rate of 1.09 percent per year. This rate is lower than the average local mortality rate of about 1.4 percent in 2000. In 2001, this group's mortality structure was 26 percent cancer deaths among all mortality causes, which is not much different from the nor-mal ratio in Central Europe.[2]

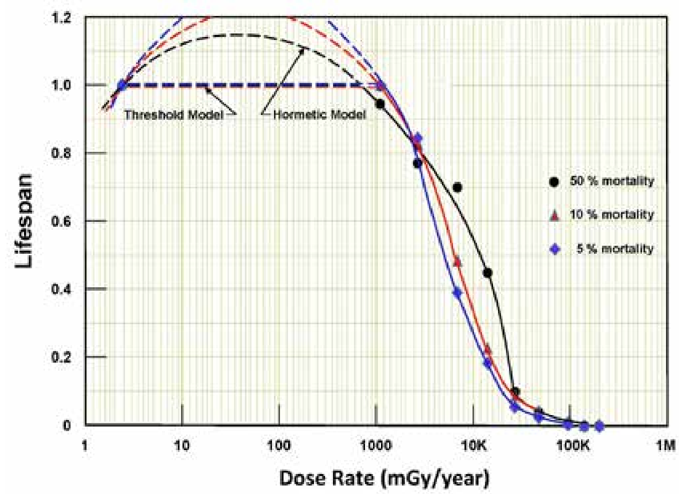

Fig. 3: Lifespans of groups of dogs at different gamma radiation dose rates.[5]

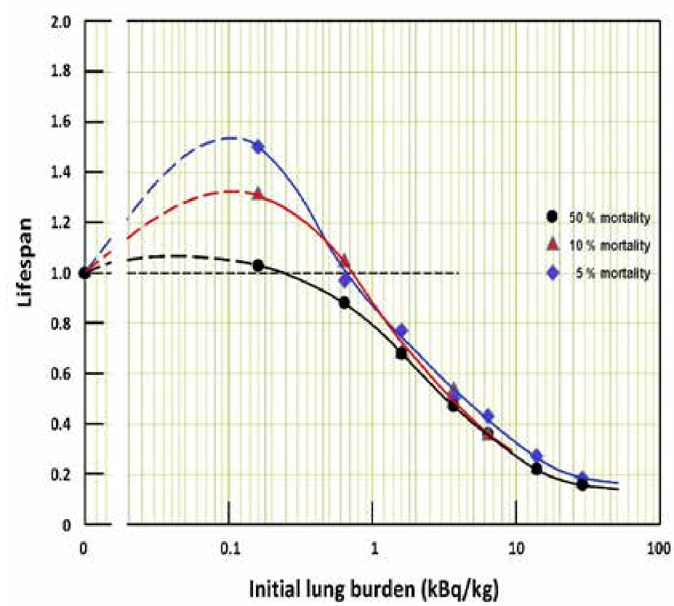

Fig. 4: Lifespans of groups of dogs at different initial lung burdens of inhaled plutonium aerosols.[5]

So how much radiation is too much? X-rays and nuclear radiation were discov-ered 120 years ago. Until the mid-1900s, before antibiotics and other modern rem-edies were discovered, medical practi-tioners used these radiations extensively to treat and cure patients who suffered from a wide variety of illnesses. In the early 1900s, geneticists began to study the incidence of radiation-induced mutations in the sex genes of fruit flies. Using very high doses at very high dose rates, they found that the mutation rate was roughly proportional to the radiation dose. By the 1920s, scientists determined a radiation level that is safe for all radiologists, a toler-ance dose of 0.2 roentgen per day, or about 700 mSv per year. This limit was based on evidence of statistically recognizable ad-verse health effects, which occurred well above this level.[3]

While this forms a reasonable base for very large doses of radiation, whole-body exposures to a very high dose of radiation at a high dose-rate are extremely r are. The much more common situation is dealing with a long-term radiation level, as in coping with widespread contamina-tion or other events that cause increases in background radiation. Because of the high natural incidence of cancers and the many factors that may affect cancer risk, it is impossible to establish a statis-tical relationship between low levels of radiation and an increased incidence of cancer.

In recent years, much has been learned about the body's responses to stress, in-cluding radiation stress, which causes cell and DNA damage.[4] Our bodies ab-sorb several million energy deposition events–so-called hits–from gamma rays and about 15,000 particles every second. A third of these are from naturally radio-active atoms in our body and the rest are from outer space and natural materials in the environment. It has been that way throughout human existence. Our bod-ies have very powerful protection systems that prevent damage, repair damaged cells, and remove and replace unrepaired cells. These systems also cope with many internal and external toxins and diseases, enabling survival to an average age of about 70 years.[4]

By far, the greatest damage to our cells is caused by breathing air. We know that oxygen combines with food molecules to produce the energy that keeps us alive, but in the 1980s, scientists discovered that oxygen also attacks and damages cells. If not for our antioxidant production, each day every cell in our body would be damaged by a billion "free radical" molecules, mostly reactive oxygen species (ROS). Our body's natural damage prevention system lowers the potential damage rate to a mil-lion DNA alterations per cell per day. Most of these are harmless, but in about 1 of 10 cells, a double-strand break occurs per cell per day, on the basis of observed data. Our repair system lowers this damage rate fur-ther to about 1 mutation per cell per day. Most of the mutations are relatively harm-less, but some change normal cells into can-cer cells. To address this hazard, our body has further defense mechanisms, such as signal-induced cell death and the immune system, which recognizes cancer cells as foreign bodies and destroys them.[4,5,6]

So how does radiation fit into this pic-ture? While the overall effects of high doses are well known, the detailed cell response mechanisms at both high and low doses are complicated and likely in-volve all levels of biological organization. Since about 75 percent of the human body is water, radiation-induced ROS is a very important effect. ROS and direct hits are a double-edged sword. They damage mol-ecules, but some of the affected cells send signals to stimulate or inhibit genes.[4,5]

To obtain a perspective on the hazard, the rate of radiation-induced DNA dam-age should be compared with the rate of spontaneous ROS-induced DNA damage. Natural radiation (1 mGy/year) induces on average about 0.01 DNA alterations per cell per day (1 percent are double-strand breaks), which is 100 million times less than the 1 million DNA alterations per cell per day that are calculated to be caused by breathing air. The radiation level would have to be quite high to induce the same rate of DNA damage as the spontaneous rate. This suggests that the observed health effects of a low dose or a low-level exposure are due primarily to cell signal-ing induced by radiation.[6]

The dose-response characteristic shown in Fig. 2 illustrates the nature of this sig-naling. As the radiation dose or dose-rate level increases above the ambient level, the stimulation of protection systems be-gins, and beneficial health effects start to be observed. As the dose or level increases further, the benefit increases until an op-timum level is reached. Exposures beyond the optimum level reveal decreased ben-efit, which suggests that stimulation has decreased and inhibition has increased. At the level at which there is no observed adverse effect (NOAEL), the health effect is the same as for unexposed individuals. If the radiation dose or dose-rate exceeds the NOAEL, the inhibition of protection systems exceeds their stimulation, and health detriment is observed. The NOAEL point is the dose or dose-rate threshold for the onset of harmful effects.[7]

Many studies have been carried out by the U.S. Department of Energy and its predecessor agencies since the 1950s to determine the effects of radiation on hu-mans. Beagle dogs are assumed to model humans well and have been the preferred choice for many studies. A recent analy-sis of data measured in two of these early studies sought to assess the effect of con-tinuous radiation exposure on longevity for radiation-sensitive and for average individuals.[5]

Figure 3 presents evidence of a dose-rate threshold (NOAEL) at about 700 mGy per year for gamma radiation−induced reduction of lifespan in dogs. Figure 4 shows evidence of a threshold (NOAEL) for inhaled plutonium particulates. Fig-ures 3 and 4 suggest an increased life-span when the radiation level is below the threshold for harm, and also demonstrate that short-lived dogs are more radiation sensitive than average dogs. Short-lived dogs benefit more than average dogs when the radiation level is below the threshold and suffer more when the level is above the threshold. This evidence also implies that even sensitive individuals do not require special protection against low-level radia-tion.[5] The acute exposure data of the Hi-roshima survivors shown in Fig. 1 are also consistent with the dose-response charac-teristic shown in Fig. 2, suggesting that the threshold (NOAEL) for a short-duration radiation dose to induce leukemia is about 500 mSv.[1]

Current regulations

After World War II, radiation protec-tion became politicized, as many scien-tists tried to stop further testing and pre-vent the development of advanced nuclear weapons. Radiation exposure has never been shown to cause hereditary effects in human populations, but X-rays and nuclear radiations are known to cause mutations in cells, which can contribute to the risk of cancer. In 1956, without documented evidence, the U.S. National Academy of Sciences issued a report rec-ommending that the risk of radiation- induced genetic mutations be assessed us-ing an LNT dose-response model.8 That is, the inferred health effect would be based on an integration of dose over time and over population groups, with no credit given for biological protection mecha-nisms. Government regulators worldwide accepted this advice,[8] causing broad pub-lic fear of low-level radiation.

The International Commission on Ra-diological Protection (ICRP) rejected the concept of a safe threshold dose limit and instead adopted a concept intended to keep cancer and genetic risk small com-pared with other hazards in life. Accord-ing to the ICRP, "Since no radiation level higher than natural background can be regarded as absolutely safe, the problem is to choose a practical level that, in the light of present knowledge, involves negligible risk."[9] Cancers that exceed the number expected to occur naturally are attributed to the "stochastic effects" of radiation. The probability of occurrence, not the severity, was assumed to be proportional to the size of the dose. The ICRP employs the LNT model to calculate the risk of "health ef-fects," which means that there is assumed to be a risk of excess cancer deaths in a population that receives a low radiation exposure, no matter how small. The risk of cancer is assumed to increase linearly with the cumulative radiation dose re-ceived (or number of cells damaged), re-gardless of the dose rate. Observations of radiation-induced beneficial effects (a low-er cancer incidence) are disregarded. The ICRP does not accept the fitting of data with the hormetic dose-response model to predict positive health effects.

The international consensus to use this method of risk assessment continues to the present time. Since 1956, all medical personnel have been taught this primitive dose-response model and the idea that every exposure to ionizing radiation in-creases the risk of cancer, cumulatively. Radiation oncologists employ high radi-ation doses locally to destroy cancerous tumors, shielding healthy tissue. Radiologists apply low-dose radiation only for medical imaging, not treatment, and they justify and optimize all such exposures to minimize the hypothetical risk of cancer.[10]

High cost of regulations

Are there reasons to reevaluate these standards? The use of the LNT model is said to be conservative, but it leads to cost-ly precautionary emergency measures that cause enormous suffering with no reduc-tion in actual health risk. In response to concerns about hypothetical cancer risks, the regulatory bodies have set exposure standards that are based on the principle of dose minimization.[11] These standards are a barrier to many applications of low doses of radiation for medical diagnostics and treatments.[12] Tight regulatory restric-tions and social fears obstruct the prog-ress of projects to construct nuclear power plants that would generate reliable and se-cure electricity.[10]

The scientific advances in radiobiology over the past 35 years have been enor-mous. The detailed cell response mech-anisms are complicated and involve all levels of biological organization.[4] Nev-ertheless, there is a good understanding of the biology that underlies the dose- response relationship shown in Fig. 2. Un-fortunately, nearly all physicians today are still being taught the recommendation of 1956, thereby perpetuating the false can-cer scare. The scientific evidence, shown in Figs. 1, 3, and 4, and the scientific miscon-duct that has occurred are being ignored.8 This information is not being adequately communicated to the public, so the ex-treme social fear of exposure to a low level of (human-made) radiation continues.

The body's immune system generally detects and destroys cancer cells to pre-vent the development and spread of can-cer. A weakened or impaired immune sys-tem is usually a precondition for cancer mortality. The DNA damage rate caused by low-level radiation has been shown to be negligible when compared with the spontaneous rate of damage that is man-aged by the protection systems (more than 150 genes), which include the immune system.[6]

Low doses of radiation stimulate the protection systems, enabling organisms to exceed their life expectancies. Studies have shown that low doses or low levels of radiation increase lifespan in animals and humans.[5,10] People living in high natural background regions tend to have greater, not shortened longevity. The 120 years of medical experience in the use of low ra-diation doses for diagnostic imaging and therapies, such as nasopharyngeal radium irradiation, have shown no significant risk of cancer or any other disease.[10] Whole-body or half-body treatments with low doses of radiation have been employed to cure hundreds of cancer patients.[10,12] It is not rational to set the safe limit at 1 mSv per year and enforce a radiation protec-tion policy of "as low as reasonably achiev-able" (ALARA) when the natural back-ground radiation level extends to 260 mSv per year in Ramsar, Iran, a city of about 35,000 people.

Overly conservative regulatory limits require hugely expensive measures to pre-vent even a minimal release of any radio-active material or an exposure to low-level radiation during normal power plant op-eration and from potential accidents of every beneficial application of X-rays, nu-clear materials, and nuclear power. They preclude or restrict the constructive use of radiation in medicine.[10,12]

Among the most egregious conse-quences of the precautionary emergency measures following the 2011 Fukushima Daiichi nuclear accident in Japan are the effects on the health of the residents (about 1,500 premature deaths among the evacu-ees) and the impact of the radiation scare on the economy. It has become obvious that society is paying a very high price be-cause of public fear of low-level radiation. The same can be said about the 1986 Cher-nobyl accident in Ukraine. The cost of the cleanup activities could have been much lower. Accident mitigation was very cost-ly when vast areas around the Fukushima and Chernobyl power plants were deemed unfit for residency or farming.

There are many nuclear sites from the weapons program that need remediation to isolate from the environment materials that are unduly radioactive. The applica-tion of overly restrictive requirements is increasing the costs for these actions as-tronomically, and is thus hampering the effective cleanup of actual hazards and nuclear wastes.

Urgent need for change

The science shows that the "no- threshold" basis for radiation regulation is wrong.[11] While there is need for a con-structive debate to establish safe limits, ra-tional thresholds should be adopted now for dose and dose rate, based on current knowledge, and all radiation protection standards should be changed to reflect such thresholds.[10]

Since there is credible evidence of signif-icant stimulatory benefits from exposures to different types of ionizing radiation, in a defined range of dose or dose rate, stud-ies to quantify and optimize these effects should be encouraged.[12]

Responsible regulations, based on sci-entific medical evidence, would restore public confidence in the safety of nuclear energy and the efficacy of medical appli-ca-tions of low doses of radiation and would avoid the needless expenditure of enor-mous amounts of money.[13]

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Status Update: Elevated Radiation Fields in The Primary Heat Transport System at The Point Lepreau Nuclear Generating Station

by W.G. COOK[1], G. BROWN[2], B. SMITH[3], E. GARDNER and P. THOMPSON[3]

[Ed. Note: The following paper was presented at the 37th CNS Annual Conference, Niagara Falls, ON., June 4-7]

Abstract

Routine dose-rate measurements taken since the refurbishment of the Point Lepreau CANDU-6 reactor had shown radiation fields at the reactor face and at some locations removed from the reactor core were three-to-four times higher than expected in 2014-2015, based upon plant experience prior to refurbishment. This finding was unexpected since much of the historical inventory of ^{60}Co and other long-lived radionuclides would have been removed when the plant was refurbished. Preliminary assessments identified the primary source as the short-lived radionuclides ^{95}Zr and ^{95}Nb and confirmed that they were most likely released from the pressure tubes, not the fuel bundles. This paper describes the steps undertaken by PLNGS to understand and mitigate the evolution of primary heat transport system radiation fields, which included analyses from PHTS crud sampling, purification filter deposits and IX resin and, modelling of corrosion product and activity transport. While the radiation fields seem to have plateaued and declined slightly, the mechanisms involved promoting release and distribution of these isotopes around the PHTS are still unresolved.

1. Introduction

The Point Lepreau Generating Nuclear Station (PLNGS) is a 700 MWe CANDU-6 unit that achieved first commercial operation in March 1983. The refurbishment of the reactor began in April 2008 and entailed replacing the 380 pressure tubes, calandria tubes and end fittings, and the 760 associated carbon steel feeder pipes. Considerable work was also undertaken on other plant systems including a mechanical cleaning of the primary side of the four steam generators tubed with nuclear grade Alloy 800. During the refurbishment project, several nuclear auxiliary systems were placed in dry lay-up with low humidity nitrogen gas for preservation during the extended outage. Sufficient lay-up conditions could never be fully established on sections of the shut-down cooling system due to passing valves used to isolate the system. PLNGS went back online in the Fall 2012 and the return to service of the PHT and secondary systems was detailed at the Nuclear Plant Chemistry Conference 2014. (Cook et al. 2014) (Stuart, Cook & Gardner 2014). Following refurbishment, the PHTS was commissioned using a non-traditional hot-conditioning process with elevated pH (lithium adjusted) and reducing conditions (hydrogen addition). This was done because the hot-conditioning process was conducted with fuel in core and conventional EDTA hot-conditioning could have led to magnetite deposition on the fuel. CNER's HEPro corrosion monitor was used throughout the hot-conditioning process to monitor the corrosion rate of the feeders and to assess when the process was complete. It should also be noted that the PHT purificaiton system was not fully available during the initial station run up and considerable corrosion products generated during the extended refurbishment outage were likely circulating throughout the system.

PLNGS had operated for nearly 26 years prior to refurbishment and traditionally had comparatively low activity levels, partially due to the efficient operation of the PHT purification system. It was thought that with the replacement of the main components of the reactor and cleaning of the steam generators, much of the historical radioisotopes would have been removed or would have decayed to a sufficient degree as to have a clean and low activity plant following restart. During a planned maintenance outage in April 2014 the radiation fields within the reactor vault were found to be significantly higher than anticipated, leading to higher than planned worker exposures. The higher- than-anticipated radiation fields continued to be observed during subsequent plant outages (both planned and forced) through 2016. Concerns were raised over worker dose and potential detrimental effects on plant cabling and sensors. A preliminary assessment determined that the PHT system was the source of the elevated fields, although elevated radiation fields were also observed surrounding the spent fuel transfer and storage pools.

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While the core of the reactor had been dismantled and replaced, the chemistry specifications and operation of the PHT system were consistent with pre-refurbishment conditions. This indicated that other factors were likely influencing the activity transport and radiation field evolution. A Systems Health Team was formed in January 2015 to identify the root cause and to recommend mitigating techniques. This paper summarizes the activities undertaken and reported at the Nuclear Plant Chemistry conference (NPC2016) in October 2016 (Cook et al, 2016), and provides an update on the current status and paths forward.

2. Elevated radiation field indications

Evidence of elevated activity levels had been gathered during plant outages (planned and forced) in April 2014, May-July 2014, March-April 2015, August 2015 and April-June 2016. An outage history following refurbishment is presented in Table 1. Routine face mapping of the radiation fields was collected for the first three outages described above and more detailed measurements of the gamma spectrometry from the PHT purification filters, ion exchange resin and limited crud sample filters was collected during the August 2015 forced outage (U30) and the annual planned maintenance outage in April-June 2016 (O16). In addition to the reactor face dose and gamma spectrometry measurements, results from routine PHT and spent fuel bay (SFB) bulk water sampling and analyses from limited PHT corrosion product transport (CPT) samples were included in the assessment.

2.1 Reactor Face Dose Rate Measurements

Figure 1a shows the measurements taken by tele-PAD dosimeters at the locations indicated, measured from the fueling machine bridge. The measurements shown cover both the East and West face of the reactor and were taken during 2014 and 2015 plant outages (O14 & U28). These results show that there is a distinct difference in magnitude between the East and West face of the reactor. The highest dose rates are on the East face and measured near the top channels of the reactor and, more specifically, on the South-East side. The dose rate measurements taken in 2015 (U28) confirmed that there had been a 57% increase in dose rate, on average, from the East face and a 52%, on average, increase in dose rate on the West face between the two outages in 2014 and 2015. Detailed measurements taken during the August 2015, April 2016, April 2017 plant outages confirmed the trend but had seemed to have levelled off or had declined slightly.

Figure 1b presents the overall face fields from the East and West faces respectively from the 61' elevation taken during the April 2016 outage (O16), and also show a definite difference between the East and West faces and a distinctly higher dose rate from the South-East quadrant, likely influenced by "shine-down" from the feeder pipes in the vertical feeder cabinet. Detailed measurements of the dose rate from the vertical and horizontal feeder cabinets have shown distinct differences between the two loops and significantly higher fields surrounding the inlet feeder pipes and around steam generator #1 (South-East side).

These measurements verified that the radiation fields, measured during plant shutdowns, are evolving over time and are higher on the East face and South loop. Comparison with pre-refurbishment dose rates collected by the PLNGS Health

Table 1. PLNGS outage history since refurbishment.

Year	Outage	Reason	Start Date	Finish Date
2012	U25	Forced: Steam cycle impurity ingress	2012-11-29	2012-12-09
2013	U26	Forced: Condenser issues	2013-04-10	2013-04-28
	O13	Planned: SGV replacement	2013-10-18	2013-11-07
2014	U27	Forced:	2014-04-05	2014-04-09
	O14	Planned: Routine maintenance outage	2014-05-03	2014-07-24
2015	U28	Forced: Fuelling machine issues	2015-03-19	2015-04-20
	U29	Forced: Reheater issues	2015-05-28	2015-06-09
	U30	Forced: Reheater replacement	2015-08-07	2015-08-31
	U31	Forced: Containment isolation valve	2015-09-26	2015-09-30
	U32	Forced: FRF leak	2015-10-14	2015-10-15
2016	O16	Planned: Routine maintenance outage	2016-04-01	2016-06-10
2016	U33	Forced: Boiler FW valve isolation issue	2016-10-06	2016-10-11
2017	O17	Planned: Routine Maintenance outage	2017-04-07	2017-05-08

Table 2. Radionuclide dose rate contribution (%) from the reactor faces.

	1995 gamma 2007 dose		2013	2014	2015-Aug		2016		2017	
	West	East	West/East	West/East	West	East	West	East	West	East
Dose rate (μSv/hr)*	86	130	230 | 410	251 | 371	n/a	n/a	n/a	n/a	126	298
Dose rate (μSv/hr)**					500	770	400	650		
Cr-51	0.0	0.0	0.0	0.0	0.4	0.6	0.5	0.4	No gamma spec taken	No gamma spec taken
Sb-122			0.6	0.1	0.1	0.1	0.1	0.1		
Sb-122	2.0	2.0	3.1	3.0	2.3	1.8	2.4	1.7		
Zr-95			14.9	14.3	24.5	22.8	21.0	20.3		
Nb-95			49.6	50.7	40.7	40.3	38.2	36.5		
La-140	12.0	3.0	0.0	0.0	0.1	0.1	0.2	0.0		
Co-58			0.4	0.5	0.4	0.3	0.3	0.4		
Mn-54	2.0	1.0	0.8	1.2	1.2	1.2	1.5	1.4		
Fe-59	5.0	4.0	2.7	27	2.8	2.4	4.8	4.4		
Zn-65			0.4	0.5	0.8	0.6	0.7	0.7		
Co-60	46.0	52.0	27.4	26.8	26.7	29.7	30.2	34.1		
Total Zr95 & Nb95	32.0	28.0	64.6	65.1	65.2	63.1	59.3	56.8		

* PLNGS measurements (point 54-East, point 61-West); ** Measurements from Kinectrics OATM surveys

Physics Department confirmed that the overall dose rates are indeed higher than seen during prior plant operation pre-refurbishment.

2.2 Reactor Face Gamma Spectroscopy

Gamma spectrometry of the reactor face is taken routinely during plant outages. The spectrometer is positioned at the same location for every measurement and is pointed directly at the centre of the reactor face. Gamma measurements were taken during the 2013 (O13), 2014 (O14), 2015 (U30) and 2016 (O16) plant outages and the primary radioisotopes observed are shown in Table 2 along with dose rate measurements that are taken from a specific location 24 hours after reactor shut down. Note, no gamma scans of the reactor face could be taken during the March 2015 plant outage (U28). More detailed measurements were taken in August 2015 but may not be directly comparable to the earlier or later measurements since the plant was shut down but the reactor was still critical, hence there could be influence from Compton scattering in the gamma spectrometry obtained. The data have been back corrected to reactor shut-down to account for the decay of the short-lived isotopes.

Results presented in Table 2 showed that the major contributor to the radiation fields on the face were Zr95 and Nb95 accounting for 57-65% to the overall dose rate. It was originally suspected that the activity would be associated with Co60 as it is commonly seen as the primary contributor to CANDU activity transport. Corrosion of out-of-core piping and components will typically lead to a build-up of Co60 over time due to its relatively long half-life and incorporation into steam generator deposits and magnetite in the headers and inlet feeder pipes. Comparing the post-refurbishment face scans to those taken pre-refurbishment it is seen that, historically, Co60 was the primary contributor to the face activity, accounting for over 50% of the dose while the combined Zr95 and Nb95 contribution was only about 35%. Other differences observed between the historical face scan data and those from post- refurbishment are the Fe59 and Mn54 contributions, which are about at half the level they were previously but are growing as the refurbished plant reaches equilibrium corrosion, activation and redistribution throughout the system. These isotopes are markers for iron corrosion and transport and the lower levels currently seen are likely the result of the lower corrosion rate of the new feeder pipe material used post-refurbishment (Lister & Lang 2002) (Palazhchenko & Lister 2014) (Walker et al. 2006).

2.3 Water Sampling and Purification Filters

Routine sampling of the PHT system water is conducted and the samples collected are measured using

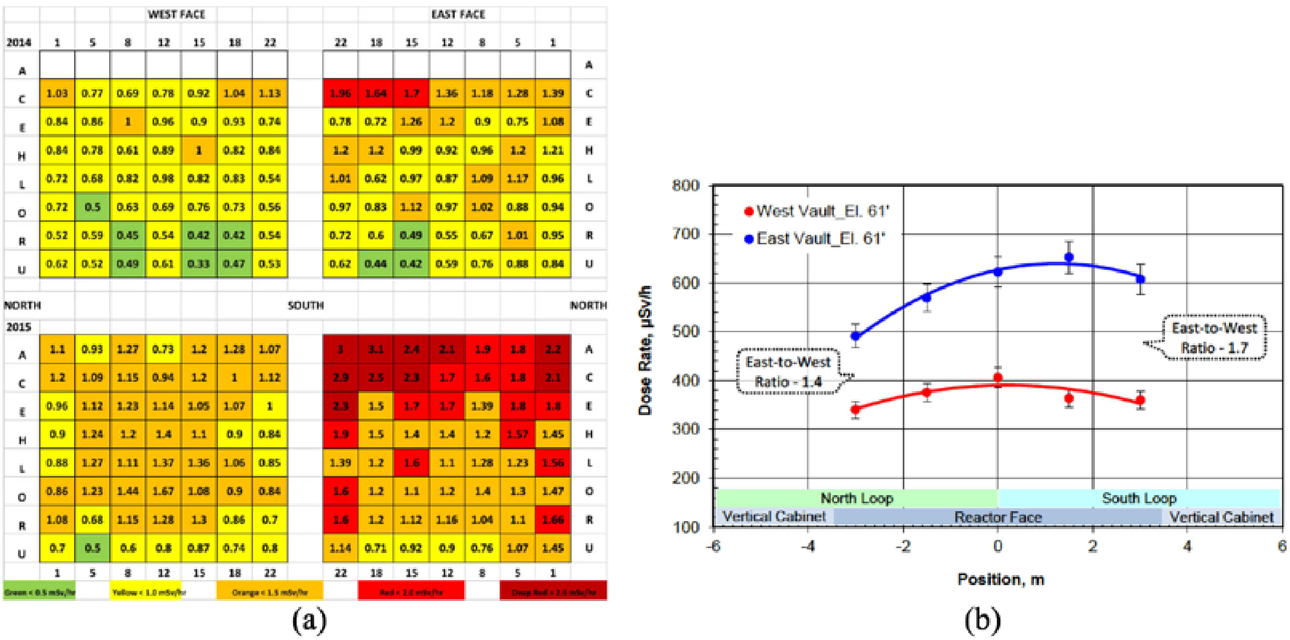

Figure 1: Reactor face dose rate maps during the 2014 & 2015 plant outages (1a) an of face fields during the O16 maintenance outage (1b).

gamma spectrometry to estimate the activity circulation throughout the system. Gamma spectrometry of bulk PHT water samples for Zr95 and Nb95 revealed occasional spikes of both isotopes, most prevalently during plant shut downs. The presence of activated zirconium alloy corrosion products suggests a periodic removal of material from the reactor core. Since zirconium and its alloys are considered nearly insoluble under PHT operating conditions, the results indicated that the products are likely circulating through the system as particulates. Evidence of Zr95 and Nb95 removal from the reactor core was also observed in the spent fuel bay, which had also been experiencing higher-than- anticipated radiation fields. Upon examination of the SFB water samples large peaks in radioactivity were observed during fuel shuffling for inspections. The overwhelming contributors to the fields were Zr95 and Nb95.

The purification system at PLNGS includes filters with either 2 µm, 0.45 µm or 0.1 µm (absolute) filter elements and two mixed-bed ion exchange columns; one in the lithiated form for continuous operation, the other in form to facilitate lithium-ion reductions and pH_a control. The PLNGS purification system operates at a flow rate of 24 kg/s representing about 0.3% of the total PHT system flow. The IX resin is typically in service for 12 months while the filters are changed as needed based upon differential pressure, usually on a 12-16 month cycle. In February 2015, the purification filter was changed from a 2 µm pore size to a 0.45 µm filter to evaluate its effect on the PHT purification and overall activity level and a 0.1 µm (absolute) filter element was installed in September 2016. Detailed gamma spectrometry could not be obtained from the 2 µm filter because the dose rate was nearly 1.0 Sv/hr at 30 cm distance. However, the gamma spectrum obtained from a distance showed an overwhelming contribution of Zr95 and Nb95 in addition to typical activated corrosion products present in the system. This is consistent with the source term for the elevated fields emanating from the zirconium materials in the core.

2.4 PHT Corrosion Product Transport Samples

Corrosion Product Transport (CPT) samples are used to estimate the bulk particulate circulating through a coolant system. Corrosion product sampling of the PHT system for CANDU reactors is a difficult procedure due to the high pressures and tritium concerns from the use of heavy water coolant so are taken infrequently and had effectively been discontinued at PLNGS. Investigation into the source term for the elevated activity fields prompted PLNGS to take several CPT samples that were collected on a 0.45 µm silver membrane filter and checked by gamma spectrometry to identify the activation products circulating through the PHT system. Table 3 presents the gamma spectrometry data from two of the crud filters collected since February 2015. Note that the short-lived Sb122 had overwhelmed the sample collected in February 2016 thus was excluded from the analysis. The next largest contributors to activity from the crud samples are the Zr95 and Nb95 combination while Sb124 is present at ~16% and Co60 is a smaller factor than expected at 5%.

2.5 Summary of Plant Observations

From the evidence gathered and the data presented above, it was clear that the overall radiation fields around the PHT circuit were higher than the pre-refurbishment values for an extended period after the reactor came back to full-power operation. Before the detailed gamma spectrometry were obtained, it was assumed that the fields were due to the release of historical activation products that were being released and redistributed throughout the PHT system. This initial assumption was shown to be invalid through use of the UNB Corrosion and Activity Transport model (see description below) that did predict a minor redistribution of historical Co60 that was contained in the steam generators but it could not come close to predicting the radiation levels observed. Additionally, it was found from the numerous samples described above that the predominant radioisotopes contributing to the fileds were Zr95 and Nb95, both activation products from in-core components, pressure tubes or fuel cladding.

While the source of the elevated fields is clearly the core materials, it was unclear if the primary contributor was the pressure tubes or the fuel cladding, or a combination of both. Also uncertain was the mechanism for the release of the materials from the reactor core that could be a form of corrosion or wear that was previously not observed. These findings prompted further investigation into the manufacturing history of the components and a detailed analysis of the activation of core materials In order to help better understand the development and progression of the radiation fields, the activation of in-core materials and typical corrosion products was modelled and prompted the station to install additional monitors around the reactor building to improve dose monitoring and to better understand the potential impact of higher fields on cabling during normal operation.

3. Modelling

3.1 Corrosion and activity transport modelling

As mentioned above, the UNB Corrosion Product and Activity Transport Model (Lister & Lang 2002) (Palazhchenko & Lister 2014) (Palazhchenko & Lister 2016) was used to assess and estimate the expected contribution from Co60 to the activity. Consideration was given to the primary corrosion-generated activation products in the assessment (Co58, Co60, Fe55, Fe59, Mn54, Cr51, Mn54, Ni63), which concluded that there would indeed be a redistribution of historical activation products (primarily Co60) from the dissolution of consolidated deposits in the steam generators. Prior to refurbishment, the outlet feeder pipes were undergoing excessive thinning through a flow-accelerated corrosion (FAC) mechanism, leading to elevated levels of iron corrosion products in the PHT system. The feeder material was upgraded in chromium content during the refurbishment outage (0.02% to 0.33% Cr) (Walker et al. 2006) (Elliot, Godin & Walker 2004) effectively reducing the FAC rates to half the pre-refurbishment values as was planned as a result of significant corrosion testing during the feeder thinning evaluation program. The efficacy of the feeder material selection was demonstrated by online measurements using CNER's HEProTM (hydrogen effusion probe) that showed typical corrosion rates between 20-35 μm/yr as compared to values of 65-120 μm/yr pre-refurbishment as shown from the HEPro data presented in Figure 2a & 2b. The lower corrosion rates allow for lower total iron corrosion products circulating through the PHT system leading to locations in the steam generator that, historically were depositing becoming dissolving, hence releasing the incorporated Co60. The modelling demonstrated that approximately two meters of steam generator tubing in the transition to the cold-leg switched from magnetite depositing to magnetite dissolving. The net release (and redistribution) of deposits from the steam generators was estimated to be 4.66 kg (per SG) over the first three years of operation after refurbishment. Even though the model predicts a release of historic activa-

Table 3. Percent contribution to the dose rate from the CPT samples.

	2015 Feb CPT Sample	2016 Feb CPT Sample
Dose rate at time of measurement:	250 uSv/hr	N/A
Nuclide	% contribution	% contribution
Cr51	0.08	0.24
Mn54	0.60	0.35
Fe59	0.27	1.10
Co60	4.79	3.79
Zn65	0.20	0.40
Nb94	0.42	0.43
Nb95	59.63	32.73
Zr95	24.70	20.60
Ag110m	0.26	2.60
Sn113	0.09	0.07
Sb124	8.75	37.55
Sb125	0.21	0.14

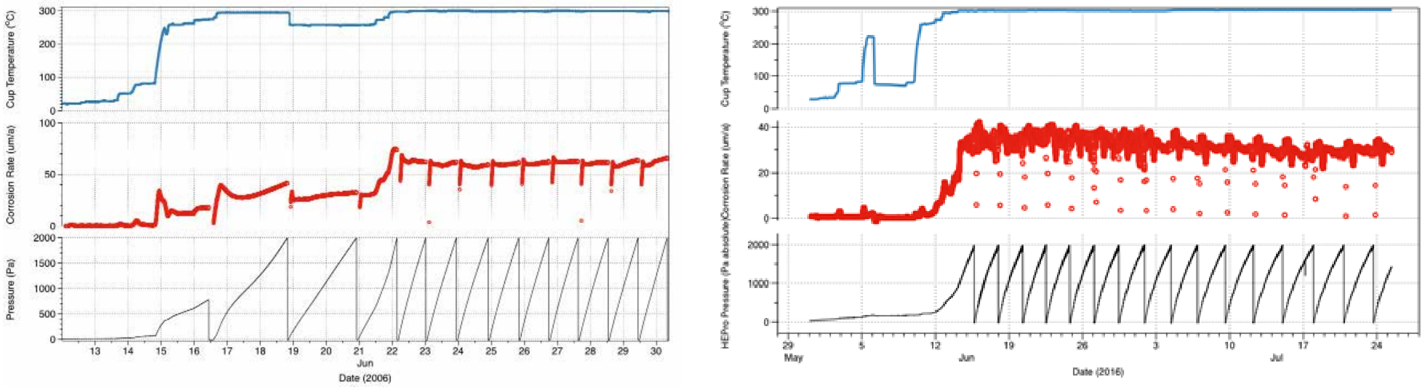

Figure 2: Operational data from HEPro™ demonstrating lower corrosion rates post-refurbishment.

tion products from the steam generators, the quantities do not account for the observed dose rates and do not account for the elevated presence of the Zr95 and Nb95 activation products observed in the face scans.

3.2 Pressure tube and fuel cladding activation modelling

To understand the mechanisms of zirconium-alloy activation and release more fully, the activation of the Zr-2.5%Nb pressure tubes and the Zircaloy-4 fuel cladding was modelled. Close attention was paid to the interactions of the minor alloying elements and primary impurities. For the pressure tube material, four stable and two unstable isotopes of zirconium (Zr90 – Zr95) are considered in the modelling while the primary isotopes of niobium are only three; Nb93 (100% abundance), Nb94 and Nb95. For the fuel cladding, niobium is replaced by 1.5% tin, which has 12 stable and 7 unstable isotopes between Sn112 and Sn125, all of which are included in the model. The activation and production of Zr95 is also a source term for Nb95 through the beta decay and the two reach a decay-equilibrium since the Nb95 half-life is nearly half that of Zr95 (35 days vs 64 days respectively) resulting in an equilibrium Nb95/Zr95 dose ratio of about 2.2. Overall, each isotope considered in the model, including antimony as an impurity (100 ppm assumed) in the materials and as a decay product, was assessed in terms of production and decay modes and the differential equations were solved on an operating time basis using the PLNGS plant power as input with an average neutron flux (f) of 2x1014 n/cm2s.

3.3 Activity Profiles

The modelling results for the activity build-up in the new pressure tubes and fresh fuel bundles are shown in Figure 3 on top of the PLNGS reactor power and evolution of the Nb95/Zr95 dose ratio. Figure 4 presents the same parameters considering a hypothetical effective full power year (EFPY) for a Zircalloy 4 fuel bundle. It is apparent from the plots that the build-in of the primary radioisotopes in the pressure tubes (Zr95, Nb94, Nb95) takes considerable time and the dose ratio of Nb95/Zr95 continues to increase with reactor operating time. The latter observation has been used in the past to assess the source term of zirconium activation products in CANDU reactor systems where ratios of above the equilibrium value of about 2.2 would tend to indicate pressure tube sources and those below 2.2 would indicate fuel cladding. This may be a reasonable assumption for reactors that have

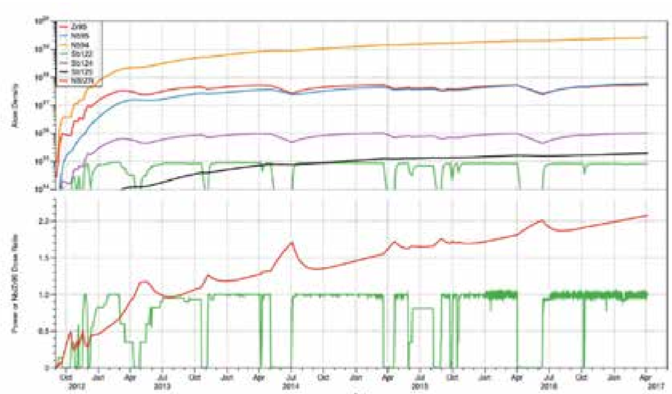

Figure 3: Build-in of activation products in the Zr-2.5%Nb pressure tube material.

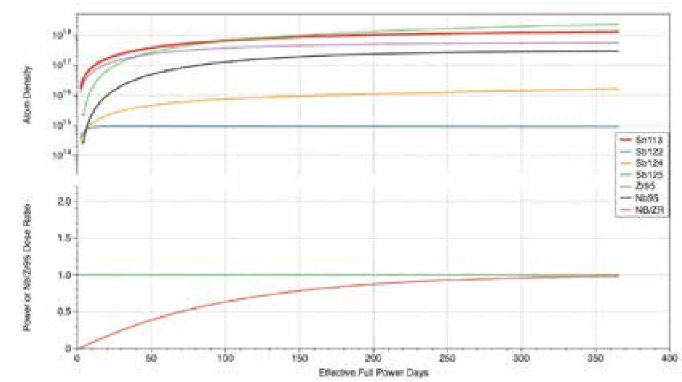

Figure 4: Build-in of activation products in the Zirc-4 fuel cladding material over 1 EFPY.

Table 4. Calculated crud age and estimate for source of Z4 & Nb activation products.

Sample/Location	Date Counted	Activity Nb94	Activity Sn113	Mapp PT (g)	Mass Zirc4 (g)	Apparent % PT material	Estimated crud age (days)	% PT material (corrected)
BO4 - crud filter	15-02-11	2.4E+03	4.94E+03	7.58E-04	6.22E-05	92.4	259	71.9
BO2 - crud filter	16-02-16	3.23E+02	5.05E+02	1.01E=04	6.36E-06	94.1	276	75.1
BO4 - crud filter	16-02-16	858E+02	3.40E+03	2.69E-04	4.29E-05	86.2	168	69.5
BO4 Sludge pile	16-05-02	1.92E+02	3.95E+02	5.75E-05	4.98E-06	92.0	253	71.6

operated for long periods, however the plot in Figure 3 demonstrates that the Nb95 build-in to the pressure tubes takes a considerable length of time to exceed the 2.2 decay dose ratio. Calculations show this to be well over five effective full power years. Nb94 is a long-lived isotope (half-life of 2.03x104 yrs) that would only be present in the pressure tubes from neutron activation of the 100% abundant Nb93. Thus, evidence of Nb94 in the gamma spectrometry results presented above indicates a pressure tube source term for the elevated fields. To identify a potential fuel-cladding source, the 1.5% tin in the Zircaloy-4 material may be used as a tracer isotope. From the plot shown in Figure 4, Sn113 is expected to build up quickly in the fuel cladding and has a reasonably long half-life (115 days) to allow for identification. Note that most fuel bundles only reside in the CANDU core for no more than a year and the ratios of isotopes used in the calculation described below consider the 1-year mark as the "average" for material release from the fuel cladding, which is considered conservative in the calculation.

3.4 Analysis and Comparison to Samples Collected

The modelling described above provides input for evaluating the source terms of the radioisotopes observed in the data collection campaigns describe earlier, including further data that became available during the planned maintenance outage in April-June 2016. As seen in the gamma spectrometry results presented in Table 3, both Nb94 and Sn113 were observed (although swamped by the Sb122 activity) and their relative activities can be used to quantify their contributions from the release of zirconium-bearing material from the reactor core.

From the CPT sample collected in February 2016, the mass of pressure tube material present can be calculated by using the activity of the Nb94 and relating it to the fraction of the isotope that would be expected to be present in the pressure tube material after the given operating time. Further, from the modelling of pressure tube activation described above, the fraction of Nb94 expected to be present in the pressure tubes in February 2016 is 0.01842 of the total niobium present. The activity of the Nb94 present (323 Bq) in the crud sample obtained equates to the presence of 2.98x1014 atoms (4.6x10-8 g) giving a total amount of niobium of 2.5x10-6 g. Since the niobium is nominally present at 2.5% in the alloy, the mass of pressure tube material contained in the sample can be estimated to be 1.01x10-4 g. Using the same approach for the Sn113 present in the sample, assuming a maximum of 1-year that each fuel bundle remains in the reactor, the mass of fuel cladding material present is estimated to be 6.36x10-6 g. This gives a ratio of pressure tube to fuel cladding material present of 15.9 indicating approximately 94% of the Zr/Nb products contained on the sample are from a pressure tube source. It must be noted that once the pressure tube or fuel cladding particulate leaves the reactor core and circulates and/or deposits on out-of-core components, the activated products decay away. Thus, crud that has been circulating around the PHT system or deposited on surfaces or on filters will have a lower specific activity than it did when it was removed from the core and the above ratio for pressure tube-vs-fuel cladding material will be skewed toward the pressure tube due to the long half-life of Nb94. To account for this, the calculated atomic fraction of Zr95 (assuming a 1-year exposure time in core for the fuel bundles and the full operational time for the pressure tubes) can be used to estimate the length of time the material collected has been removed from the core, normalized to the calculated mass of material present on the sample. The sum of the expected Zr95 from the pressure tube and fuel cladding gives an approximate "crud age" for each sample, from which the initial Sn113 mass can be estimated. In performing this calculation for the February 2016 CPT sample, an average "crud age" of 275 days is predicted based on the Zr95 present. Back correcting the Sn113 mass for 275 days of decay leads to an original mass of 3.35x10-5 g giving a ratio of 3.02 between the pressure tube and fuel cladding, effectively indicating that 75% of the material is from the pressure tubes. A summary of this approach applied to several of the recent samples obtained is presented in Table 4 and indicates that the primary source term for the Zr and Nb activation products present in the system is likely the pressure tubes.

4. Discussion

It is clear from the field measurements presented above that Zr95 and Nb95 are the predominant radioisotopes contributing to the observed elevated radiation fields surrounding the PHT system. It was concluded that the pressure tube material is the likely source through evaluation of the gamma spectrometry from the samples collected. Additional observations of higher than normal radiation fields attributed to the Zr95 and Nb95 pair that were also observed in the spent fuel transfer and storage pools and the pipework associated with their purification systems, indicating that there is "loose" material attached to the fuel bundles that is being carried over to the fuel bays. The outstanding questions are: what is the removal mechanism and why is it different than before? And, how can the cause be eliminated or at least mitigated?

Indications of possible pressure tube wear were present during ultrasonic inspections conducted during the 2014 maintenance outage (O14). While there was no apparent cause for concern, the inspection report indicated that the frequency of scratches and wear marks observed was higher than expected for pressure tubes that had only been in service for just over one EFPY. Possible causes could be abnormal wear between the bearing pads of the fuel being added / removed from the fuel channels during the refuelling operations on the pressure tubes or that acoustic / harmonic vibrations within the fuel channels are causing the fuel bundles to move slightly within the channels and wear the pressure tube. It was also thought that the indications may have been caused during initial plant start up following the refurbishment due to a significant crud burst from imperfectly laid up systems (shut-down cooling system for example) or from FME circulating through the PHT system. The inspection report noted that the overall ID surface of the pressure tubes appeared roughened with a distinct lattice pattern, likely introduced from the honing process during manufacture. A roughened surface may lead to potential under-deposit or crevice corrosion under the bearing pads of the fuel bundles; however, it was confirmed that the pressure tubes originally met the roughness specification of the supplier.

A review of the used fuel inspection reports did not give any indications of abnormal corrosion or degradation of the fuel, although it was noted that PLNGS had used fuel from a different supplier for the initial refuelling following the refurbishment up until early 2015. Follow up with both suppliers has provided no additional information or potential fuel-related causes to the possible increased wear of the pressure tubes. The follow-up with the fuel suppliers included a compliancy assessment for the fuel supplied and an assessment of hardness for the bearing pads and pressure tube. In co-operation with both fuel suppliers, hardness tests were conducted on blank samples of fuel cladding and bearing pads in different stages of fabrication as well as on cut-offs of the pressure tubes retained from PLNGS during their installation. The results showed pressure tube and bearing pad Rockwell Hardness of 98 HRBW and 88 HRBW respectively indicating that the pressure tubes are the harder material and that wear on the pressure tubes should be minimal. Radiation hardening should be similar for both materials.

Just prior to and during the April 2016 outage (O16), detailed dose rate and gamma spectrometry measurements were conducted on the PHT purification system that included measurements on the spent IX resin (transferred out of the IX columns in late February 2016) and the 0.45 µm filter element removed in February 2016. The Zr95 and Nb95 pair were the predominant radioisotopes observed on both, and the presence of these radioisotopes in the IX resin was notable indicating that the particulate are very small and can pass through a 0.45 µm filter or, that the new sub-micron filter was bypassing to some degree. A replacement 0.1 µm (absolute) filter was installed September 2016 and had shown little pressure increase over its operation up to the planned maintenance outage in April 2017 (O17).

The use of colloidal-removal ion-exchange resins for increased efficiency in particulate removal could improve upon the overall purification of the system and lower the overall transport of Zr95 and Nb95 and help to reduce the fields.

While improved purification efficiency would help to minimize the radiation fields throughout the system it does not address the cause of the removal of unexpected amounts of zirconium alloys from the reactor core. The build-in period for the pressure tube activation was demonstrated to have reached its plateau (Figure 3) so it is not expected that the radiation fields due to Zr95 and Nb95 will increase further, which is encouraging from a radiation protection perspective. However, from the materials and mechanistic perspective, what caused the release from the pressure tubes and what long-term impact the mechanism may have on their continued fitness-for-service is still unknown. The most comprehensive and informative data has been gathered through analysis of the very limited number of corrosion product transport samples collected from the PHT system. Comparison between the PLNGS CPT samples and those obtained from other CANDU plants may reveal clues as to the mechanisms involved as would a detailed review of the historic gaseous fission product (GFP) data from PLNGS and other similar CANDU plants.

5. Conclusions

The observation of higher-than-expected radiation fields around the primary heat transport system of PLNGS had prompted the station to perform a significant review and evaluation into the cause. From the chemistry and operational perspective, the plant has been run as per the best practices developed and employed prior to the refurbishment outage and a review of the PHT system chemistry history has demonstrated very good adherence to the chemistry specifications. By conducting detailed dose rate mapping and gamma spectrometry of the reactor, corrosion product transport samples and the PHT purification system, it was concluded that the source term for the elevated radiation fields is Zr95 and Nb95 activation products being released, primarily from the pressure tubes. Preliminary inspections of the pressure tubes and spent fuel bundles have not identified the mechanism of release from the reactor core but detailed modelling of their neutron activation has demonstrated that the radiation fields should have plateaued and should not increase further, in the absence of significant fuel failures.

It appears that the overall dose rates around the PHT system have declined, based upon detailed measurements during the 2016 maintenance outage (O16) and limited measurements taken during the 2017 maintenance outage (O17). While apparently not necessary at this time, methods for mitigating elevated fields will be investigated including the use of novel sub-micron filters and ion exchange resins. Work to elucidate the mechanism(s) that was causing the zirconium alloy release from the reactor core is still needed since increased purification efficiency may help to reduce the transport and overall activity in the system but the mechanism(s) that resulted in the material release and transport is still unknown. Further investigation into the manufacturing history of the pressure tubes and comparison with additional OPEX from other CANDU plants is on-going and PLNGS intends to implement detailed outage activity transport modelling (OATM) surveys in the 2018 maintenance outage to provide additional data.

6. Acknowledgements

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Embalse Refurbishment: Update of Progress

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[Ed. Note: The following paper was presented at the 37th CNS Annual Conference, Niagara Falls, ON., June 4-7]

Abstract

Following several years of detailed planning and preparation, the Embalse NPP (Córdoba Province, Argentina), was shut down on December 31, 2015, to embark on the execution phase of the Life Extension Project (LEP). Typically, the Outage Critical Path activity for the life extension of a CANDU6 reactor consists of the Fuel Channel and Feeder Replacement, named "Retubing". For this activity, Candu Energy, Inc engineering as well as previously used and successfully proven tools and procedures are being used. With this being the third CANDU6 retubing campaign, the processes and tooling have been further refined to minimize the critical path duration. NASA is leading the execution of the work with on-site support from Candu Energy technical advisors. So far, the plant has been successfully defueled and drained, and the reactor component replacement activities are advancing well with the removal phase already complete.

Keywords: Plant Life Extension, CANDU 6, Fuel Channel Replacement, Refurbishment.

1. Introduction

This paper provides an overview of Embalse retubing activities, with particular emphasis on the improvements devised –and, in some cases, already executed–, demonstrating how advancements in retubing techniques continue to be introduced. This paper will also include references to some other important refurbishment activities such as steam generator replacement, Digital Control Computer (DCC) replacement, reactor up-rating, turbine and balance of plant refurbishment or replacement, Class III diesel generators replacement, moderator heat exchanger replacement, and safety system improvement and modernization, among others.

2. Embalse Refurbishment Project2

2.1 Project Description

The Embalse LEP has an ambitious scope which includes the following main activities been leading by NASA with technical support from the original designers and main components manufacturers:

- Reactor retubing
- Steam Generator replacement and Primary Heat Transport Up-rating
- DCC replacement
- Turbine and Balance of Plant (BOP) Refurbishment and Up-rating
- Diesel generator replacement
- Moderator Heat Exchanger (HX) replacement
- Safety system improvements and modernization

This paper will focus on the retubing part of the project and will also make mention to the other activities listed above.

2.2 Project Schedule

The Embalse LEP consists of three phases:

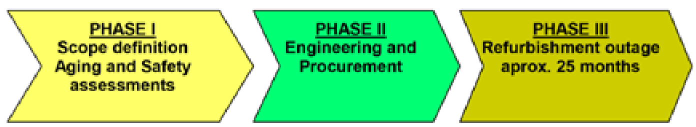


Figure 1: Main LEP Phases

These three phases, even when they are planned in a sequence, sometimes overlap in order to accommodate the manufacturing of the long lead components. In addition, some activities that would normally be included in the plan during Phase I come up later in the sequence and are thus incorporated during Phase II or III.

Phase I started in 2006 and Phase II started in 2009. The Outage was originally planned to start in January2013, but it was postponed many times in order to accommodate to the country's need for energy. The plant´s design Effective Full Power Hours (EFPH) were stretched from 210.000 to 225.000 based on the plant condition limitations, particularly calandria tube/LISS nozzle contact, feeder thinning, steam generator support degradation, and pressure tube creep.

The actual outage start date was December 31, 2015. The current retubing schedule is based on previous CANDU 6 experience. With regard to retubing activities, Annex A shows, as an example, an update of the latest removal activities.

1 Nucleoeléctrica Argentina S.A., Argentina

2 SNC-Lavalin Nuclear Inc. (Candu Energy, Inc), Mississauga, Ontario, Canada

3. Retubing

Most of the reactor components for retubing were manufactured locally in Argentina. The first step in the localization of components was a careful assessment of the manufacturing companies' capabilities. CONUAR was eventually selected and a very exigent qualification program started with the partnership of AECL and then Candu Energy Inc. CONUAR has been the traditional fabricator of nuclear fuel for the NASA fleet and thus already had an established manufacturing and quality program.

After the qualification process concluded, contracts for supply of channel closures, shield plugs, end fitting assemblies, pressure tubes, calandria tubes and feeders were entered into. It was not an easy task, but the reactor components were successfully fabricated and delivered in time to meet the outage schedule. Candu Energy Inc. was again part of this through a post-order agreement, providing expert technical assistance and support through the Design Deviation Request (DDR) process.

In 2011, a contract was signed with Candu Energy Inc. for supply of the engineering design, documentation and engineered tools required for the retubing. A contract for on-site technical assistance (advisory service) was also made. An important difference with previous CANDU 6 retubing projects was that this time NASA (the owner) would take responsibility for the execution of the work at the site.

During the retubing, all 380 fuel channels are removed and reinstalled, including the feeders (up to the header nozzles). The most relevant activities successfully completed thus far are:

- Reactor Shutdown and defuelling
- Interference removal
- Retube Power Distribution System (PDS) installation
- Retube Active Ventilation System (AVS) installation
- Primary Heat Transport System (PHT) draining and drying
- Moderator draining and drying
- Closure plugs removal
- Graylock disconnection
- Feeder removal
- Positioning Assembly (PA) Hardware removal
- Reactor face and back wall insulation removal
- Fuel Channel Platform (FCP) installation
- Bellows weld cutting
- Pressure tube (PT) cut
- End Fitting (EF) removal
- Pressure Tube removal
- Calandria Tube Insert (CTI) release and removal
- Calandria Tube (CT) removal
- High radiation waste handling and storage
- Bellows and Lattice Tube Inspection
- Calandria Vessel Inspection

Additional support equipment was also manufactured locally, for example, the equipment used to drain and dry the PHT and the moderator. This equipment has already been successfully used.

Record-keeping software named *Ñandu* was developed by the Embalse team. This software provides an electronic and interactive format of the reactor face instructions to aid the Retube Operations Centre (ROC) operators in the step-by-step control of the face activities and record keeping. It was used for the first time during the bellows weld cut and, and then for all the removal series. It has proven to be effective to manage the reactor face work to ensure all steps are completed correctly, including all Quality Control points. This will constitute an important support during installation.

For each retubing series, a detailed log of the delay causes was kept (*Ñandu* includes the facility to track the reasons for, and durations of, the delays). Since the planned project schedule includes contingencies which would have assumed some delays, not all the production stops produce a delay in relation to the planned (overall) schedule, but an analysis of these production stops allows identification of improvements in production time without sacrificing safety or quality.

Another contributor to the success of this project has been the series team organization. Very early in the project, the retube work scopes were divided up into work "series", and leads (typically engineering staff) assigned. This allowed the leads to focus and plan the work several months in advance of execution, to ensure that outstanding issues were resolved, and any changes were incorporated throughout the life cycle (training, tooling, execution, and closeout). A good example of this is the project FARO team. This is the team that was dedicated to the laser measurements to support retube, including establishing the Global Coordinate System (GCS).

The next sections contain a description of the main issues encountered in the course of each series. Additional details about each retubing series can be found in the series' reports, in which all the delays are listed and classified.

Valuable recommendations were made by production staff to mitigate the impact that production stoppages have on the schedule. The measures proposed were always discussed and agreed with Candu advisors before executed. Examples of mitigating actions are also included in the briefing of the main series below.

3.1 Channel Closure Removal

On July 22, 2016, channel closures began to be

Figure 2: CP removal

sprayed with CRC (a penetrating oil) in preparation for the series. On the 23rd, removal of 754 plugs began using the EGIF (Enhanced General Inspection Fixture) tool.

All the channel closures- except for 6 - were removed by July 25. A contingency disassembly plan was applied for the other 6.

A simple but very important lesson learned from this series was the amount of CRC to be applied to the channel closures is important in order to facilitate its removal. Also, considerable amounts of magnetite were encountered in the channels during this first reactor face series.

3.2 Feeder Removal

Removal of feeders lasted 14 days, two days ahead of schedule. 120 trades participated in the series execution.

For the purpose of removal and installation, the feeders are divided in upper and lower feeders. The vertical portion of the lower feeders was removed using the feeder platform, and the horizontal portion was removed using the scissor lift removal of support elements was done in parallel. The upper feeders were then removed from the center to the sides.

This series involves the highest risk from a radiological protection perspective, specifically the spread of contamination, however this did not materialize. A total collective dose of 786 man-mSv resulted from this series, less than half of planned. No unplanned exposures occurred.

The following are some of the events that caused delays:

- The scissor lift failures and batteries charging strategies became critical to maintain production.
- Unclear expectations regarding exposure rates caused a lot of back and forth in the activities associated with the waste box.
- The sheer amount of Personal Protective Equipment (PPE) used to continue production 24/7 in a physical demanding task like this was so high that sometimes it was difficult to provide new elements on time.
- A number of upper feeders were left longer than stipulated, so they had to be re-cut.

All the removed feeders were stored in boxes in the medium radiation waste storage. The series was completed without any personnel accidents.

3.3 Fuel Channel Platform Installation

The FCP installation took one month including a 7-day delay in relation to the planned duration of 23 days. This series involved the ingress to the Reactor Building of the largest retube components with very narrow access ways to reach the reactor face, consequently it took longer than foreseen.

A lesson learned from this series was that it is very important to have a detailed tracking, identification and localization of each part, because a lack of spare parts, however small, has a noticeable effect on a

Figure 3: FCP column lifting

series. Detailed coordination of the groups and having enough qualified staff for heavy movements is also key for the job success.

For this series, all activities in the vault were closely monitored and directed from the Retube Operations Center (ROC). The ROC was supposed to enter operation later, but its use is very advisable as a communications control point and for directing the work.

Figure 3 below shows the ingress of the main FCP components into the reactor vault.

3.4 Bellows Weld Cutting

This was the first series carried out using automated tools. Tool commissioning was an important challenge and, in most of the following series, the difficulty to meet the schedule increased during the "Transition In".

This series was done on schedule, including commissioning.

The learning curve took longer than foreseen, however higher production rates than in previous CANDU 6 retube projects were achieved further into the series, once the tools were properly set-up. The same happened in many other series during the retubing.

Although this series was completed on schedule there were areas for improvement. The issues that caused the majority of delays were:

- Problems with tool-channel alignment using the vision system.
- A partially broken clamp on the mechanism that grips the cutting tool to the end fitting (the clamps were recalibrated).
- Other events from other activities in the RB (energy supply interruptions, broken water line).

3.5 Pressure Tube Cut

This series also includes push and rotation of the EF to demonstrate the cut was successful.

The learning curve took longer than foreseen, because of many minor issues. For example the vision system set-up presented several problems not described in the WP or in the OPEX. The series was completed as scheduled, with higher productivity towards the end, which compensated for the initial delay. One significant cause of delays for this series was related to shield plug removal and reinstallation. This was related to the high level of magnetite found in the fuel channels.

This series involves the first reactor face work with open channels. The total collective dose was 196 man-mSv and no unplanned exposures occurred.

3.6 End Fitting Removal

This series constituted a challenge in terms of the amount of people involved and different activities developed in parallel. This series has the highest number of tools and the largest number of waste transfer movements in all the retubing. It was the first use of the High Radiation Waste Storage Facilities, also known as Canisters. The lattice tube and bellows protective sleeves (Thumbtacks) are also installed during this series. There were logistics groups working all the way between the canisters and both reactor faces. Transportation, transfer station activities, transfer flasks activities, removal in the reactor face, lattice sleeve (thumb tack) ingress to the Reactor Building and installation, ROC operation, etc., were all activities that had to be well coordinated to support 24 hours a day operation.

Figure 4: Reactor face view during the EF removal

The series was completed in 22.3 days for production and 7.5 days for tool commissioning instead of the 19 days and 5.3 from the plan. The transition-out took 2.2 days, just as scheduled.

The learning curve took longer than foreseen. Multiple tool complications were detected at the beginning of the job. For instance alignment issues which were solved in the field improving transfer station engagement.

An important delay of almost one day was experienced due to a broken coupling on the Fuel Channel Platform A2 column. This was caused by a misalignment during FCP installation. There was also a failure in the 10-ton crane on the C side. This is a very important support for the series and the issue had a very big impact on the schedule: an estimated 24h delay until the root cause was identified (memory card failure) and a few additional minutes per cycle was added for the remainder of the series as operators improved their technique to perform manual alignments to compensate for the vision system that continued to perform poorly.

In addition, a repetitive failure in the vision system affected the normal development at the start of the series. Vision alignment was dropped early in the series,

3.7 Pressure Tube Removal

This series has the highest inventory of radioactive material involved. The Volume Reduction System (VRS) was used for the first time in this series.

The Transition In took three days longer than planned while the series execution took 6 days less. The series was planned to be completed in 27 days and was completed in 21 days for production.

A total of 20 lessons learned were obtained from this series, among which the most important are:

- The vision alignment system continued to perform poorly so movements were done using manual off-sets.
- The primary filters consumption was three times more than the estimated due to both a configuration change (design change) in the tool which made the tool ventilation flow paths more efficient, and the increased amount of magnetite found in the pressure tubes. Six additional filters were received from Canada and fifty more were locally procured in a very short time.
- Despite the OPEX included in the documentation supplied by Candu to prevent collisions, accidental collision events still occurred. Hence, to prevent future events, additional interlocks were introduced to the equipment to avoid uninformed handling of the equipment.
- It is worth mentioning that, unlike all previous retubing projects, there was no need to change on the press on the VRS during this series, or subsequent series that us the VRS. . Apart from a few leaks and alignment issues in the flasks, the VRS had an outstanding performance.

3.8 Calandria Tube Insert Release and Removal

This series was planned to be done in 19 days. The release phase took 7 days and the removal phase took 9 days.

The series execution was completed in 16 days, 3 days faster than planned; however, the transition in for this series took 20 days instead of the 4.6 days planned. This constitutes the biggest delay up to this point in an individual activity; the main reasons for the delay were:

- Lack of an ordered plan for testing and troubleshooting (the induction coil and transformer on one of the machines was replaced as it was suspected faulty, however it was later determined these components were not the issue). Replacement of the induction coil due to performance issues because it was suspected (it did not meet the parameters specified on the procedure).
- Transformer replacement was not required, also done on the advice of TOCCO representatives.
- Incorrect internal tool wiring.
- TOCCO control computer replacement
- Mockups were found to be out of tolerance causing difficulties on tool setup, which, in turn, caused ground failures and damage to the induction coil. Also were not representative of the reactor condition
- Alignment issues finally fixed using the FARO laser measurement system to align the induction heating system to the channel.
- Frequency adjustment to follow Candu procedures by changing the capacitors on the mockup. When moved to the reactor, the tool had a different response than in the mockup, so the amount of capacitors was changed many times until the desired frequency values were reached.
- Delays in tooling installation
- Interference with other simultaneous activities at the RB (unplanned events). Water falling from Steam Generator drilling activities.
- Insufficient qualified technical advisors planned for execution - the first week there was only one advisor for a 24/7 job - and different criteria among the advisors.

As a result of the activities mentioned above, the personnel involved became highly qualified, with a deep understanding of the tool and increased confidence for the execution phase.

All calandria tube inserts were successfully removed with pull forces well within specification.

3.9 Calandria Tube Removal

The series finished on March 14th, lasting 17 days, 4 days ahead of schedule.

Overall the tooling performed well in this very successful series, however there were some issues with the following:

- Complications and delays related to the alignment of the Small Waste Transfer Flask (SWTF) when lifted into the VRS
- Dimensional tolerance issues with the Lattice Sleeve Handling Tool (LSHT) guide sleeves producing interferences with the thumbtacks.
- Oil leaks caused by hose failure on the VRS (though fewer than in the PT removal)

3.10 High radiation waste handling and storage

High radiation waste handling and storage work is in the hands of a dedicated team, who executed the whole removal series, from EF removal to CT removal. The work was finished on March 15th, 2017. Precautions were taken in order not to interrupt storage work in case of rain, but reality showed that it is very difficult to work with wet surfaces and equipment.

The total Collective Dose for the high radiation waste handling and storage work was 43.58 man-mSv, with an average of 0.41 mSv per person.

There were many lessons learned from this series as it got very close to become critical path several times - and in a few cases, it did. The following are some of the most important lessons we can mention:

- Containers dimensions in relation to the transfer flasks. Some design improvements should be made in order to avoid the container being locked into the shielding. Some of the containers were not made to specification by the local supplier and all the flasks have exactly the same dimensions.
- Gantry crane design speed was very low and, with the Canisters configuration, it took quite a long time to make the required movements. During the most demanding series, such as EF removal, the use of an additional mobile crane was required to keep up with production on the reactor face. The picture below shows night work on canisters using a mobile crane.
- As waste storage is usually not on the critical path it does not always get the same attention as work on the reactor face and is normally carried out by an ad-hoc group. There was not the same level of detailed OPEX available before the work started. Many contingencies (related to radiation protection, availability of PPE, dimensional requirements, etc.) were not documented and were addressed as problems arose.
- Flasks have different dimensions and, consequently, behave differently. The mechanisms that open and close the container and flasks doors are susceptible to human error and could expose the personnel to radiation.
- The Container Loading Device (CLD) would require a more careful commissioning to start production.
- Special consideration should be given to the service supply in the canisters location to avoid later modifications and their potential impact on the schedule.

4. Working Groups / Organization

The training plan was affected by the delay in outage start. This gave us a chance to train for a longer period and with higher confidence on the tools field operator.

Operator training was carried out as follows. First, Candu advisors trained a group of trainers and series leads who, in turn, trained the supervisors and skilled workers. Then, closer to the series start, the rest of the staff that would be involved in the execution of the work received training. Finally, once the training stage was over, all the personnel were evaluated and received qualifications to do the job. Given the duration of the

Figure 5: Waste storage during night using mobile crane

retubing outage, training of the last group was done in parallel to execution of the series tasks. For this purpose, two groups – called white and blue – were put together so they could alternate between training and working.

For the retubing, an assessment was done of staff required for execution of each of the series. Personnel

Table 1: Collective dose

Activity	Collective Dose (man-mSv)
Draining and other preparatory activities	1269.99
Feeders removal	786.00
PT cut and removal preceding Series	1072.92
PT cut	204.90
EF removal	182.81
PT removal	196.01
CTI removal	144.07
CT removal	58.56
Total removal dose	3942.29

doses and minimum staff required for the removal phase were then calculated, taking into account the exposure rates measured and with data from previous retubing projects as reference.

There are a total of 635 people working on the retube, and the maximum dose required occurred during the EF Removal series. It is important to note that, at the same time, there were other groups training for the next set of series as well as teams devoted to working on other aspects of the series, such as documentation, work permits, qualifications, tool commissioning, and so on.

The manpower resources were originally estimated based on the experience from previous retubing projects. The same criterion was used for the ALARA program in relation to the estimated individual and collective dose. For different reasons, like the time at low power and shut down before start the refurbishment outage, but also thanks to a dedicated effort of the RP team, the collective dose at the end of the preparation and removal phase was much lower than expected. The table below shows the collective dose for the retubing main series.

5. Other activities

5.1 Steam Generator Replacement

The Embalse Steam Generators (SGs) have exhausted their design life with a fairly good performance regarding plugged tubes. However, because of the flow-assisted corrosion in the tube support plates and the impossibility of replacing such plates, the SGs had to be replaced. The refurbishment outage was our only opportunity to incorporate that activity.

The SGs are manufactured locally in Argentina at IMPSA while the SGs tubes are manufactured by CONUAR. Many renowned companies (such as PCI, Mammoet, Electroingeniería) are involved in the replacement work.

For more information, see paper SG Replacement presented at this same conference (See reference [1]).

5.2 Digital Control Computer Replacement

The plant Digital Control Computers (DCCs) are being replaced because they have become obsolete. The hardware was supplied in 2014 by L3MAP, a Canadian company who also supplied these components for previous CANDU6 refurbishment projects. The software was supplied by Candu Energy, Inc.

The DCCs were installed in January, 2017, with the assistance of L3MAP advisors. An acceptance test was carried out during February and March of 2017. All these activities were performed with the support of Man Power's local staff, gathering very valuable experience for the future operation of these important systems.

The experiences and lessons learned from the work done previously were incorporated to this activity through the specifications supplied by Candu Energy Inc.

5.3 Turbine and Balance of Plant Refurbishment

5.3.1 Up-rating

In order to uprate the station output, a contract was signed with Ansaldo to increase the minimum power by 35.4 MWe (the real increased power will be measured after return to power).

For this purpose, a high pressure preheater was added between the feed water pumps and the main feedwater valves. The preheater uses the reactor's additional power, increasing feedwater temperature by 30°C (from 158°C to 188°C). As the water enters the SGs with more energy, and the pressure and exit temperature are not increased, the only way to keep the system variable is through an increase in flow.

5.3.2 Refurbishment

The turbine was replaced with forged mono-block turbines instead of the former shaft with shrink disks. The forged turbine weighs 120 tons, was made in Japan, and machined in Italy. 20 tons of scraps were removed and other 20 tons were added in the form of accessories such as blades, labyrinth seals, etc.

The high and low pressure turbine seals were also replaced for new ones with higher efficiency. Steam from the high-pressure turbine was drained in order to heat up the new heat exchanger mentioned above in the same quantity as the increased flow into the SGs.

The main generator stator was rewound and all the auxiliaries were changed for complete new skids (seal oil, cooling water, and cooling hydrogen). All 32 main BOP valves were also refurbished and its actuators were refurbished in Italy. The P102 outlet valves (check and MV) were also changed.

The feedwater valves (main and start-up) were all replaced as well as the MSSV and ASDV valves, which are provided by Candu Energy Inc.

The P102 valves were refurbished in Italy; the whole hydraulic system and the I&C provided by Ansaldo will be replaced.

The main transformers were replaced by new ones manufactured by ABB Brasil.

5.4 Standby Diesel Generator Replacement

The standby diesel generators (4 x 3.5 MVA each) were replaced due to obsolescence and low reliability issues on the automatic voltage regulator (excitation system). Both the diesel engine itself and the control system were obsolete.

The new ones - already on site - have a higher capacity (4 x 6.2 MVA). The new diesel generators are supplied by Ansaldo. The engine is Caterpillar (US) while the Generator is NIDEC (Italy). The cooling is now done with heat exchangers independent of the service water. The ODD and EVEN bus bars were segregated in regard to both fuel and control.

5.5 Moderator Heat Exchanger Replacement

The moderator HXs have shown some problems with U-bend vibration during operation. These problems have been fixed using pig tail supports, but the aging assessment of those heat exchangers indicate that they had to be replaced.

The manufacturing of those components was done locally by CONUAR and they are now ready to be installed. The installation of the HXs is planned to be done between May and July, 2017.

All large bore stainless steel main moderator gate valves have also been replaced.

5.6 Safety System Improvements and Modernization

Following are described the most relevant design changes related to nuclear safety:

Fuel channel design: The new fuel channels to be installed at Embalse incorporate design modifications incorporated in other CANDU6 life extension projects. Worth noting are a longer space along the channel to allow more room for unconstrained fuel string expansion when the fuel elements heat up, and a glass peened matte surface on the outside of the calandria tube to increase moderator subcooling margin.

Trip Coverage: Reactor trip coverage will be improved by both adding new trip parameters for events already covered with other existing parameters, and by adding new trips to cover events not considered in the original design basis, but required to be considered by the newer regulations. Also some existing trip setpoints will be tightened to improve timely event detection.

Among the trip parameters that will be added, for either Shutdown System 1 or Shutdown System 2, are high and low PHT pressure, and Steam Generator low level. New trips will be added on high and low moderator level, to cope with moderator events. Regional overpower protection will be improved by adding new in-core flux detectors for both shutdown systems.

Reliability of the Emergency Core Cooling System (ECCS): Several design changes are being implemented for this important system, to improve the reliability of both initiation and operation of the system. Worth mentioning here are the following:

- Increase of the main LOCA signal setpoint (i.e. low PHT system pressure) and reduction of the high Reactor Building pressure conditioning signal, for earlier LOCA detection.
- Addition of a new conditioning signal on sustained low PHT system pressure, to ensure automatic initiation of the ECC system for the smaller LOCAs (for which the high Reactor Building conditioning setpoint could not be timely reached).
- Automation of the transfer between the medium and low pressure phases of the ECC system operation, to avoid a manual operator action.
- Duplication of key system valves to increase reliability.
- Addition of alarms to monitor system operation from both MCR and SCA.

Protection of the PHTS pumps and adjacent piping against high vibrations: Cavitation of the PHTS pumps could arise from low PHTS pressure, as a result of a LOCA. If this were to occur to all four pumps at the same time -common cause-, then a multiple-point LOCA could take place, for which the ECC system is not designed. To prevent this event, a new trip of the pumps on this parameter is being added. Upper thrust bearing break could result from loss of the cooling service water. To avoid this event, a new trip on high bearing temperature is being added.

Plant robustness against a seismic event: Two key systems present in the CANDU 6 design to cope with seismic events are the seismically qualified Emergency Power Supply (EPS) and Emergency Water Supply (EWS). Both of these systems will undergo major upgrades in order to improve the plant response to strong earthquakes. The old EPS is being completely replaced by a new, increased capacity system that will supply the ECCS pumps. The old diesel driven EWS pumps are being replaced by new electric pumps of increased capacity, supplied from the new EPS. The increased EWS pumping capacity will be used to provide seismically qualified cooling water to the ECCS heat exchanger. Also, the two valves that are key to the EWS operation are being duplicated, for increased reliability.

Plant robustness against severe accidents: Several design changes are being implemented with the intention of better coping with beyond design basis accidents. The most important ones are the following:

- Addition of a make-up water line from outside the Reactor Building to the Calandria Vessel, to provide make-up water to the calandria vessel in the event of a beyond design basis accident involving severe core degradation. Keeping the calandria vessel filled with water ensures in-vessel retention of the degraded reactor core.
- Addition of a make-up water line from outside the Reactor Building to the Calandria Vault, to provide make-up water to the calandria vault in the event of a beyond design basis accident, if in-vessel retention has failed.
- Addition of pressure relief capacity for the Shield Cooling System, by means of a seismically qualified rupture disc assembly. The increased relief capacity prevents that excess heat and pressure endanger the

calandria vault integrity and heat sink.

- Addition of a Containment Filtered Venting System, to provide relief for the reactor building in the event of a severe accident. Filtered venting protects the building without the release of significant amounts of radioactive products.

Plant robustness against a loss of Class IV / service water: On loss of Class IV, one of the main issues was the logical loop between the Class III diesels generators required to supply service water pumps which, in turn, had to supply diesels cooling. New Class III diesels cooled by air were installed breaking this disadvantageous logic loop.

Hydrogen control in the reactor building: Passive autocatalytic recombiners (PARs) will be installed at various rooms inside the reactor building, to ensure hydrogen concentrations remain below flammability levels in case of accidents leading to significant hydrogen generation (i.e. LOCA plus loss of ECC injection, which is a design basis event for the CANDU 6). The presence of the PARs will also be beneficial for the long term reduction of hydrogen in case of severe accidents.

6. Conclusions

The Embalse life extension project is the most extensive refurbishment of a CANDU6 station performed to date (see Section 2.1 above), involving upgrades throughout the station, including: retubing, steam generator replacement, control computer replacement, turbine and balance of plant refurbishment (including turbine replacement and up-rating), diesel generator replacement, moderator heat exchanger and valve replacement, and safety systems improvement and modernization. Starting from a very aggressive schedule, there have not been significant delays through removal and up to the start of the installation phase.

Most of the critical path consists of retubing activities, but, for a couple of months, Steam Generator Replacement will be part of the critical path as well. The initial planned duration was 26 months.

Until now, two of the main stages of the retubing have been completed, namely, the preparation and removal phases, and the inspection phase is nearing completion. The critical path activities that involve the highest risk from a radiological protection perspective are over and the total dose is about half of the estimated. No unplanned exposures have occurred. This is clearly one of the many successes of the project to date.

The Candu Energy Inc. supplied tools have exhibited very good performance, however, there is always room for improvement which is only logical considering the complexity of the engineered tools and that field use on-reactor occurs only during retubing outages (i.e. only once every five years or so). The aspects to improve have been identified during each retubing series and, in many cases, corrective actions have been taken.

Some key areas that most need improvement for the CANDU6 retubing tools are the following:

- Vision Alignment System: Machine vision targets and overall reliability.
- Volume Reduction System: Flask lifting and alignment, hydraulic systems leak control
- Waste Handling and Storage Equipment: Should be less susceptible to human error and more flexible in their use (e.g. include possibility of using forklift)
- Reactor Inspection Cameras - overall reliability and maintainability.

Some key areas of improvement for the execution include:

- Spare Parts management should be more efficient
- Series Readiness process should be more comprehensive
- Tooling commissioning should be done in a more comprehensive way and both well in advance of the field work and after Transition In to the reactor face.

With regard to retubing procedures and documentation, they have proved to be very complete and adequate for the tasks at hand, requiring only logical adjustments to adapt to Embalse's organization.

NA-SA reactor face and ROC teams performed very well. They were well trained, well organized. They managed the work efficiently, with very little time lost during production (after the learning curve and getting the tools working smoothly). They were a key to achieving the record high production rates during many series, and recovering time lost during transitions and the early part of the series.

7. References

[1]- Pablo Javier Luna, James Jesko, Stefan Bostelaar and Ricardo Sainz, "Embalse Steam Generator Replacement Project: Main Challenges And Progress Update Of The Implementation Phase",

Meet the President – Daniel Gammage

Daniel Gammage has been in the office of President of the Canadian Nuclear Society for several months. He moved from 1st vice-President /President Elect automatically at the Society's Annual General Meeting held June 4, 2017, in Niagara Falls, Ontario, immediately before the CNS Annual Conference. His term runs until the 2018 AGM which will be held in Saskatoon.

Daniel is quite proud of being a representative of the younger generation within the Canadian Nuclear Community, having become President at the age of 32. Daniel started working with the CNS very early in his career, and was assisting with conference organization while still a co-op student. After some recruiting by John Roberts and Bill Schneider, Daniel became a CNS member and ran for Council – a position he has enjoyed ever since.

In his short term as President thus far, Daniel has demonstrated his desire to see the CNS expand its influence and prosper in the process. As stated in his first remarks as President in 2017, Daniel made it clear that it is the responsibility of all members of the Nuclear Community to stand up for their respective industries and to play a role in educating the public on the positive aspects of nuclear energy and nuclear science and technology. He made it clear that this type of advocacy can be as simple as having conversations with friends and family while assembled around a dinner table or while sitting around a camp fire. If we, those individuals who work in this great technological area, do not stand up for our industry... who will?

In his time as 2nd VP, 1st VP, and now President, Daniel has shown that he is not one to accept the status quo – although he has shown the ability to balance new ideas with those that could be considered tradition. This will be important to growing the CNS, old ideas and rituals can be challenged, and through careful consideration the CNS will move forward in its ability to spread the good messages of the nuclear community, both across Canada, and the rest of the world. Daniel has a challenge as President this year due to the number of new members on Council – following a very active and successful election. Daniel has shown patience and a willingness to educate the new Council where appropriate on not just what needs to be done, but also why the CNS does things the way it does – he relies on some of the more senior members to help guide these aspects. Following the prior example of Paul Thompson's term as President, Daniel has increased the frequency of meetings of the CNS Executive to deal with items promptly.

Daniel has a broad experience, in various aspects of Life Cycle Management, Fitness-for-Service, and Component Assessment, this experience has included various challenging technical roles and management both at Babcock & Wilcox Canada Ltd. (now BWXT) in Cambridge Ontario, and Amec Foster Wheeler Nuclear Canada in Toronto, Ontario.

Biography

Daniel was born in Cambridge, Ontario in 1984. He attended Blair Road Elementary School for K-6, St. Andrew's Senior Public School for 7-8, and Galt Collegiate Institute for High School. Daniel was on the Senior side of Ontario's famous double cohort year, he was part of the last group to receive Ontario's Grade 13 education. Daniel had always enjoyed working with his hands – something fostered through woodworking with his Grandfather from a very young age – he excelled in technical education as a result. Up until Grade 11, Daniel had fully planned on becoming a Tool-and-Die maker and tailored his education towards that goal. However, his desire for creativity and design (mixed with exceptional academic performance) caught the eyes of his teachers, especially his Technical Design and Engineering teacher, Mr. Hoekstra. One day after class, Mr. Hoekstra took Daniel aside and convinced him that Mechanical Engineering was the clear path forward for him – Daniel never looked back after this. However, there was a very strong competition for Daniel's career as he was also very involved in music, playing the piano, trombone, and tuba, while also singing in various school and community choirs. For a time, Daniel seriously considered pursuing Music at the University level as many of his friends were doing. However, again, Mr. Houghton, the school's much beloved music teacher helped Daniel figure this out, Music was always something that Daniel could do and participate in even without formal education – engineering was not. Following graduation from high-school, Daniel continued in singing in the St. Andrew's Presbyterian Church Choir in Kitchener Ontario, while also co-leading the church's Bell Choir. With the decision made, Daniel knew that he faced stiff competition in getting accepted to Engineering programs at top Universities, being there was twice the number of students applying that year due to the elimination of Grade 13. Daniel focussed his efforts during his Senior years – helped along by friendly competition from his peers who were also seeking similar goals, and emerged in the top percentile of GCI graduates in 2003 – he was accepted to every Engineering program he had applied to. Daniel points to this friendly competition between his friends as the reason as to how he was able to succeed – and still sees this as a valuable motivator today.

Following high-school, Daniel attended the University of Waterloo in Waterloo, Ontario, obtaining, in 2008, a BaSc. (Honours) in Mechanical Engineering with an Option in Management Science, in his senior years, Daniel focussed on courses on Material Science, Fluid Mechanics, Heat Transfer, and Thermodynamics. Over six co-op work terms (two at Dana's Advanced Engineering group in Oakville, Ontario, and four at Babcock & Wilcox Canada Ltd. In Cambridge, Ontario) Daniel found his way to the Nuclear industry. Daniel liked the work so much that he took on part-time employment at Babcock & Wilcox Canada during his third and fourth year University Studies. He then joined Babock & Wilcox Canada Ltd. Permanently following University graduation in 2008, While there he worked in the Life Cycle Engineering Group. Shortly thereafter, later in 2008 after attending the CNS CANDU Maintenance Conference which he helped organize in Toronto, Ontario, Daniel strolled up Bay Street and met a girl that he had been talking to for a few months on the phone, Sophi-Anne Martino. Three years later, in 2011, Daniel and Sophi-Anne were married in a lavish Italian Wedding in Ancaster/Hamilton, Ontario. Daniel then moved to Sophi-Anne's hometown of Ancaster, Ontario where they still reside today.

Three years later, an opportunity presented itself at Amec Foster Wheeler Nuclear Canada in Toronto, Ontario. Daniel accepted this opportunity and started work there in the Risk Informed Engineering Section in January of 2015. Since then, Daniel has progressed to become the acting manager of the Steam Generator Assessment and Risk Informed Engineering Section as well as the Inspection and Maintenance Engineering Section, he currently has 12 employees and 15 contractors reporting to him in this role.

In the small amount of time that remains after considering his work, high degree of commuting, and CNS role responsibilities, Daniel spends his time working around the house on various projects, working on cars, and helping Sophi-Anne with various aspects of her passion in the healthcare industry. Daniel and Sophi-Anne do not have any children as of yet, but they spend time spoiling a very active Beagle named Toby and a cat named Tuxedo – both of whom are best friends.

Professional background

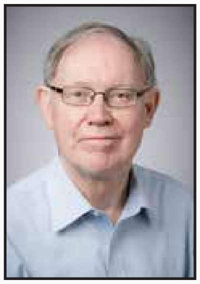
During his time at Babcock and Wilcox Canada, 2005 – 2014 (when including part-time and co-op employment), Daniel worked in the Life Cycle Engineering Department in a Project Engineering role. This experience allowed him to learn the finer details associated with inspecting, maintaining, and operating Nuclear Steam Generators, heat exchangers, and other plan components. As Daniel became more confident in his abilities and role, he moved to a lead position within the Life Cycle Engineering Group which was responsible for providing outage support and technical support for Steam Generators and other components at various Nuclear plants around the world. Over this time, he helped develop new fitness-for-service methodologies for newly discovered degradation mechanisms – helping keep equipment running longer in a more predictable way. His strong interest in Business Development led him to visiting many Nuclear Utilities across Canada and the United States, as well as presenting at several CNS, and EPRI conferences on various topics associated with component ageing and life cycle engineering. Over this time, Daniel became licensed as a Professional Engineer in the Province of Ontario.

In 2014, an opportunity presented itself at Amec Foster Wheeler Nuclear Canada. Daniel joined them in January of 2015 as an Engineer in the Risk Informed

Engineering Section, supporting fuel channel and steam generator assessment work. In mid-2016 Daniel became the acting Section Manager of the newly created Steam Generator Assessment and Risk Informed Engineering Section, then acquired responsibility for the Inspection and Maintenance Engineering Section later in 2017. This is the role that Daniel currently serves, with 12 employees and an additional 15 contractors reporting to him.

CNS involvement

Daniel has been an active member of the Canadian Nuclear Society since 2012 coinciding with his first year on Council. However he started working with the CNS much earlier on along with Bill Schneider and John Roberts assisting to organize several conferences: CANDU Maintenance Conferences, Steam Generator Conferences, Nuclear Plant Chemistry, and others. Following taking a position on CNS Council, Daniel became the Chair of the Design & Materials Division where he organized INCC 2015 and other initiatives. As 1st VP, Daniel then organized the 2017 Annual Conference which was held earlier this year in Niagara Falls, Ontario. He has presented at, and attended many CNS Conferences and Courses over the years. Daniel has also assisted the Program Committee and the Honours and Awards Committee.



Nuclear Energy Academy Annual General Meeting

The Annual General Meeting of the International Nuclear Energy Academy (INEA) was held in Vienna, Austria on September 18, 2017 on the fringes of the General Conference of the International Atomic Energy Agency (IAEA).

At this meeting Dr. John Luxat, Professor in the Department of Engineering Physics at McMaster University, was elected Chairman of the INEA for a two year term starting in January 2018.

He assumes chairmanship from Dr. Phillip Finck, **Sr. Scientific Advisor** in the Laboratory Director's Office, Idaho National Laboratory

Background
International Nuclear Energy Academy

The International Nuclear Energy Academy (INEA) is an honour society of the international nuclear scientific and engineering community. The objective of the INEA is to foster the development and utilization of the peaceful application of nuclear energy in a safe and economic manner through-out the world.

INEA conducts studies, discussions, and develops recommendations for the international nuclear community on generic issues relevant to nuclear energy matters.

INEA was founded on 22 June 1993 by the International Advisory Committee - IAC, a group of international nuclear experts.

INEA has more than 130 experts as its international members in the nuclear energy fields and holds the Non-Governmental Organization Status of IAEA.

Publications

Energy, Electricity and Nuclear Power Estimates for the Period up to 2050

Reference Data Series No. 1

The 37th edition of the annual Reference Data Series No. 1 contains estimates of energy, electricity and nuclear power trends up to the year 2050, using a variety of sources, such as the IAEA's Power Reactor Information System and data prepared by the United Nations.

IAEA-RDS-1/37, 139 pp.; 62 figs.; 2017; ISBN: 978-92-0-106117-1, English, 18.00 Euro

Electronic version can be found: http://www-pub.iaea.org/books/IAEABooks/12266/Energy-Electricity-and-Nuclear-Power-Estimates-for-the-Period-up-to-2050

Cyclotron Based Production of Technetium-99m

IAEA Radioisotopes and Radiopharmaceuticals Reports 2

This publication presents a comprehensive overview of the technologies involved in the production of cyclotron based 99mTc. These would include techniques relevant to preparation of targets, irradiation of targets under high beam currents, target processing, target recovery and quality control of the final product. The publication provides broad information, well supported with references, on improved production routes and improved separation and purification of cyclotron based 99mTc. These approaches achieve high specific activity and chemical purity of 99mTc suitable for labelling molecules of medical interest and also enable spare capacity to be available at medical cyclotron centres. The readership of this publication is scientists interested in translating this technology to practice, technologists already working with cyclotrons wanting to enhance the utility of the existing machines and managers who are in the process of setting up facilities in their countries. Students working towards higher level degrees in related fields may also benefit from this publication.

STI/PUB/1743, 59 pp.; 48 figs.; 2017; ISBN: 978-92-0-102916-4, English, 33.00 Euro

Electronic version can be found: http://www-pub.iaea.org/books/iaeabooks/10990/Cyclotron-Based-Production-of-Technetium-99m

Managing the Financial Risk Associated with the Financing of New Nuclear Power Plant Projects

IAEA Nuclear Energy Series No. NG-T-4.6

Mitigation of the financial risks attendant on a nuclear power plant new build project is a key to ensuring project viability. This publication emphasizes how various risks – including those typically considered to be 'engineering risks' – will give rise to such financial risks. It then introduces the linkage between efficient financial risk allocation/mitigation and the cost of capital, and sets out a range of mechanisms which can be used to manage and allocate risks efficiently, thereby minimizing the cost of capital and enhancing project economics. At a practical level the publication provides an insight into the concerns, modes of thinking, and language which a nuclear new-build proponent may expect to encounter within the financing community as they seek to develop their project.

STI/PUB/1765, 93 pp.; 33 figs.; 2017; ISBN: 978-92-0-100317-1, English, 32.00 Euro

Electronic version can be found: http://www-pub.iaea.org/books/IAEABooks/11140/Managing-the-Financial-Risk-Associated-with-the-Financing-of-New-Nuclear-Power-Plant-Projects

Instrumentation and Control Systems for Advanced Small Modular Reactors

IAEA Nuclear Energy Series No. NP-T-3.19

This publication emphasizes the key cross cutting technological issues associated with instrumentation and control systems and human system interfaces that arise from the specific behaviour and operational characteristics of advanced small modular reactors (SMRs). It is intended to assist Member States in understanding current knowledge, practices, design and architecture, implementation, operating and maintenance related aspects with I&C systems in SRMs, as well as for discussing the challenges and issues that need to be resolved in this field in the first phases of design and implementation by Member States active in SMR development.

STI/PUB/1770, 95 pp.; 27 figs.; 2017; ISBN: 978-92-0-101217-3, English, 39.00 Euro

Electronic version can be found: http://www-pub.iaea.org/books/IAEABooks/10960/Instrumentation-and-Control-Systems-for-Advanced-Small-Modular-Reactors

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http://www-pub.iaea.org/books/feedback

Obituary

Prof. Riccardo Bonalumi

I am very sorry to report that Professor Riccardo A. Bonalumi, retired Professor at the University of Toronto, passed peacefully, surrounded by his loving family on Friday September 8, 2017 at the age of 82 at Sunnybrook Hospital. Riccardo left behind by his loving wife Marlaena, children Nadine and David, and granddaughter Zoë. A mass of Christian burial took place at Holy Cross Funeral Home in Thornhill on September 14, 2017. Donations to the Heart and Stroke Foundation and Princess Margaret Cancer Foundation would be appreciated. Prof. Bonalumi was a long-time CNS member.

Riccardo A. Bonalutni was born in Bergamo, Italy in 1935. He received a Master's in Mechanical/Nuclear Engineering at the Polytechnic Institute of Milan, and a Doctorate in nuclear Reactor Physics at the University of Rome. In the period 1959-69, he pursued nuclear research at the Italian Research Laboratory CISE in Milan. He continued work in R&D as Principal Investigator for Light Water Reactor lattice physics methods at Combustion Engineering Inc., in Windsor, Connecticut, then as Director of the Reactor Analysis and Computation Division back in CISE.

Riccardo emigrated to Canada in 1976, joining the staff of Ontario Hydro and becoming Supervising Design Engineer, Advanced Physics, in the Nuclear Studies and Safety Department. In the period 1976-1983, he continued working at Ontario Hydro on the physics of safety systems, reactor physics, computational methods, advanced concepts analysis for slightly-enriched CANDU systems, and development of theoretical models for two-phase flow.

Riccardo Bonalumi was always interested in teaching, and in 1978 he joined the University of Toronto, Department of Chemical Engineering and Applied Chemistry, on a part-time basis. He continued as an Adjunct Professor, and supervised many B.A.Sc., M.A.Sc, M.Eng. and Ph,D. students in nuclear-related research. Prof. Bonalumi was appointed to a full-time tenured position in November. 1983. He published many articles in the scientific and technical literature on reactor physics, uranium-water lattices, and the physics of two-phase flow. In 1982-83, he developed a unique method of generating accurate in-reactor flux maps by combining in-core detector data with theory. I was fortunate to interact often with Riccardo during my time in the Reactor Core Physics Branch at AECL Sheridan Park.

Unfortunately, Riccardo suffered a debilitating stroke in the 1990s, which left him with movement and speech difficulties, but his mind was clear to the end.

Ben Rouben

Publications

Research Reactors for the Development of Materials and Fuels for Innovative Nuclear Energy Systems

IAEA Nuclear Energy Series No. NP-T-5.8

This publication presents an overview of research reactor capabilities and capacities in the development of fuels and materials for innovative nuclear reactors, such as GenIV reactors. The compendium provides comprehensive information on the potential for materials and fuel testing research of 30 research reactors, both operational and in development. This information includes their power levels, mode of operation, current status, availability and historical overview of their utilization. A summary of these capabilities and capacities is presented in the overview tables of section 6. Papers providing a technical description of the research reactors, including their specific features for utilization are collected as profiles on a CD-ROM and represent an integral part of this publication. The publication is intended to foster wider access to information on existing research reactors with capacity for advanced material testing research and thus ensure their increased utilization in this particular domain. It is expected that it can also serve as a supporting tool for the establishment of regional and international networking through research reactor coalitions and IAEA designated international centres based on research reactors.

STI/PUB/1728, 27 pp.; 2 figs.; 2017; ISBN: 978-92-0-100816-9, English, 32.00 Euro

Electronic version can be found: http://www-pub.iaea.org/books/iaeabooks/10984/Research-Reactors-for-the-Development-of-Materials-and-Fuels-for-Innovative-Nuclear-Energy-Systems

GENERAL news

(Compiled by Colin Hunt from open sources)

Darlington Refurbishment Project on Budget and Schedule

The Unit 2 reactor face at Darlington Nuclear GS.

On Sept. 20, workers severed the final feeder in Unit 2, the first of four reactors at the power plant undergoing mid-life refurbishment. Removal of the 960 feeder pipes, which carry the coolant required to cool nuclear fuel, is the first step in preparing for the disassembly of the unit, and sets the stage for replacement of parts. After the pipes were removed, they were safely packaged and taken to a licensed facility for storage.

The refurbishment of Darlington Nuclear's unit 2 is now 25 per cent complete, on time and within the approved budget as confirmed in Ontario Power Generation's (OPG) 2017 second quarter refurbishment progress report.

960 feeder pipes in the reactor were severed and removed.

"Darlington Nuclear is one of Ontario's most important generating assets by supplying almost 20 per cent of Ontario's electricity needs," said Dietmar Reiner, OPG's Senior Vice President for Nuclear Projects. "The refurbishment of Darlington will extend the life of this station for another 30 years while creating thousands of jobs."

The Darlington Refurbishment project is a made-in-Canada initiative, with 96 per cent of related expenditures happening in Ontario. Right now, over 5,000 workers are on site and an additional 500 workers joined the work on the project in September. Over a hundred Ontario-based companies are involved in the project supporting thousands of jobs across Ontario. The next major phase of the project is disassembling the nuclear reactor.

Bruce Power Conducts Unit 6 Inspection Prior to Refurbishment

Bruce B Turbine Hall.

A significant planned maintenance and inspection outage got underway on Bruce Power's Unit 6 last week as it is the final planned outage on the unit before it undergoes a four-year Major Component Replacement (MCR) project to completely refurbish and extend the operating life of the unit.

Unit 6 is the first Bruce Power unit scheduled for Major Component Replacement starting in 2020.

"We've conducted meticulous preparation and planning for this outage involving teamwork and input from across the company," said Len Clewett, Executive Vice President and Chief Nuclear Officer. "When the breaker closes at the end of this campaign, we plan to run Unit 6 safely and reliably to January 2020 when the MCR project will begin."

Approximately 14,000 tasks, many of which will help extend the life of the unit, will be completed with a total investment of more than a $100 million. Unit 6 will return to service in the fourth quarter of 2017 in time to meet Ontario's high winter demand.

"We have a large electrical program and to support that Bruce Power has hired 150 additional electricians to help complete the work," said Clewett. "Safety will continue to be paramount and we've enhanced our training and qualifications for incoming supplemental staff to ensure that everyone goes home safely at the end of every day."

Durham Region Reactors Awarded Highest Safety Ratings

The Canadian Nuclear Safety Commission (CNSC) has awarded Ontario Power Generation's (OPG) Darlington and Pickering nuclear stations its highest safety ratings. For eight consecutive years Darlington Nuclear achieved the highest possible safety rating, while Pickering Nuclear achieved its highest possible safety rating for the second year in a row.

"Ontario Power Generation is committed to providing clean energy while protecting the public, the environment and our staff," said Glenn Jager, OPG's Nuclear President and Chief Nuclear Officer. "Achieving the highest ratings at both of our nuclear stations recognizes OPG's dedication to continuously improve safety."

CNL Receives Strong Interest in Small Modular Reactors

Canadian Nuclear Laboratories (CNL), Canada's premier nuclear science and technology organization, announced today that over 70 organizations have submitted responses to its Request for Expression of Interest (RFEOI) on small modular reactors (SMRs); a strong gesture of support from a broad range of stakeholders representing key areas of a potential SMR industry. CNL launched the RFEOI this summer to gather feedback and initiate a conversation on the potential for an SMR industry in Canada, and the role CNL can play in bringing SMR technology to market.

The RFEOI prompted input from SMR technology developers, potential end users, and other interested parties and stakeholders, including host communities, the nuclear supply chain and research and academic institutions.

CNSC Completes Review of Disposal Facility Draft Eis

The Canadian Nuclear Safety Commission has completed its technical assessment of a draft environmental impact statement (EIS) for a proposed Near Surface Disposal Facility (NSDF) for radioactive waste from Canadian Nuclear Laboratories' Chalk River site. CNL must now address all federal and public comments received on the proposal before submitting its final EIS.

The CNSC has identified "a number of areas" where additional information will need to be included in the final EIS and other technical supporting documentation, it said. A consolidated table of federal comments, including the CNSC's assessment and those of other federal authorities participating in the review, has been submitted back to CNL for action. The list includes "almost 200" information requests and comments, the CNSC said.

CNL must now address all federal and public comments received and submit a final EIS to the CNSC. The regulator will then determine the completeness of the information provided in CNL's submissions, and may request further information. CNL is expected to submit the final EIS in January and the commission expects to hold a public hearing on the project in July.

Nuclear Reactors Operate through Caribbean Hurricanes

The reliability and importance of nuclear energy was recently demonstrated during Hurricane Harvey and in its aftermath. The two nuclear reactors at the South Texas Project, located 90 miles southeast of Houston, operated at 100 percent power during and after the storm to provide lifesaving power to over 2 million Texas residents. The reactors were designed to withstand Category 5 hurricane conditions. Provisions were in place to immediately shut down the plant if needed; however, the units remained at full power. Reactor units in Louisiana, near Baton Rouge and New Orleans, also operated at full power during and after the storm. By contrast, the storm has left refineries shut down, pipelines closed, and resulted in extended interruption to wind and solar power sources.

Nuclear plants located in Florida weathered through Hurricane Irma. These power plants had previously withstood Hurricane Andrew with Category 5 force with damage only to periphery systems. One reactor unit was safely shut down at the Turkey Point site just north of Miami while the other unit remained in full operation. Further up the East Coast, the two units at St. Lucie remained in operation during the storm. After the storm, power was reduced in Unit 1, due to salt buildup on insulators in the switchyard.

Also, as the storm shifted westward, the NRC carefully monitored conditions associated with operation of the Hatch Nuclear Power Plant in Georgia and the Farley Nuclear Plant in Alabama. It was determined that conditions would not impact safe operations of these reactors and the reactors were maintained at full power.

Fukushima Accident Had No Effect on BC Fishing: BC Oceanographer

Radioactive contamination following a nuclear power-plant disaster in Japan never reached unsafe levels in the north Pacific Ocean for either marine life or human health, says a British Columbia scientist.

Chemical oceanographer Jay Cullen of the University of Victoria has monitored levels of contamination from radioactive isotopes, used in cancer therapies and medical imaging, since the meltdown of three reactors at the Fukushima Daiichi plant in 2011 following a tsunami triggered by an earthquake.

"We're confident in saying that the levels that we see now in our part of the Pacific from Fukushima are below those levels that represent a significant health risk either to the Pacific Ocean or to human beings in Canada or the west coast of North America," said Cullen, who is one of nine international authors of a study published last week on the findings in Environmental Science and Technology.

"We haven't been able to detect changes in the amount of these artificial isotopes that are in our Pacific salmon and steelhead trout or shellfish that we've collected all up and down the coast," he said.

China's 37th Reactor Enters Commercial Operation

Unit 4 of the Fuqing nuclear power plant in China's Fujian province has completed commissioning tests and now meets the conditions for entering commercial operation, China National Nuclear Corporation (CNNC) announced September 18.

The 1087 MWe CPR-1000 unit completed a series of commissioning tests, including a load test run and a test run lasting 168 hours, CNNC said. Although the company must still obtain necessary permits and documentation, the unit can now be considered to be in commercial operation.

First concrete was poured for unit 4 in December 2012 and its dome was put in place in June 2014. The process of loading the 157 fuel assemblies into the reactor core began on 13 June this year and was completed six days later. The unit achieved a sustained chain reaction for the first time on 16 July and was connected to the grid on 29 July.

CNNC's Fuqing plant will eventually house six Chinese-designed pressurised water reactors, the first four being 1087 MWe CPR-1000 units. Units 1 to 3 entered commercial operation in November 2014, October 2015 and October 2016, respectively. So far, the units at Fuqing have generated 38 TWh of electricity, avoiding the consumption of over 12 million tonnes of coal and the emission of about 40 million tonnes of carbon dioxide, according to CNNC.

CNNC now has 17 power reactors in operation, with a combined generating capacity of 14,340 MWe.

China's State Council gave final approval for construction of Fuqing 5 and 6 in mid-April 2015. First concrete was poured for the fifth unit in May 2015, while that for unit 6 was poured in December. These will be demonstration indigenously-designed Hualong One reactors. CNNC expects all six units at Fuqing to be fully commissioned and put into operation in 2021.

Parliamentary Secretary Rudd Hosts Meeting to Promote Nuclear Energy in International Clean Energy Efforts

Kim Rudd, Parliamentary Secretary to Canada's Minister of Natural Resources, the Honourable Jim Carr, and colleagues from the United States and Japan co-hosted a side event at the International Atomic Energy Agency (IAEA) 61st General Conference in Vienna, Austria, to discuss opportunities to raise the profile of nuclear energy in multinational clean energy forums. At the event, where Ms. Rudd served as head of the Canadian delegation, there was broad agreement among participants to work together to ensure that nuclear energy collaboration is pursued under the Clean Energy Ministerial (CEM).

Nuclear energy enables safe, reliable, competitive and clean energy solutions that support economic development, energy security and environmental objectives. The scale and sophistication of nuclear research and development, coupled with the need for strong government-to-government involvement in nuclear relationships, make multilateral collaboration a key factor in advancing innovative nuclear energy technologies.

"Canada is pleased to work with colleagues from the United States and Japan to promote the importance of nuclear energy in clean energy innovation. Canada has vast expertise and technological capacity in the nuclear sector, and, as part of our government›s commitment to the industry, we are pursuing new opportunities for international collaboration in this important area," Ms. Rudd said.

Canada is taking a leadership role through the CEM to raise the profile of nuclear energy in international discussions and efforts on climate change and clean energy. Canada, the United States and Japan intend to co-sponsor the development of a nuclear energy work stream under the Clean Energy Ministerial Framework to be launched at the next CEM meeting, which will be hosted jointly by the European Commission, Denmar k, Finland, Norway and Sweden in 2018. Canada will host the CEM in 2019.

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Scholarships in Nuclear Science and Engineering at Canadian Universities

The Canadian Nuclear Society (CNS) is pleased to offer scholarships to promote Nuclear Science and Engineering to students at Canadian universities.

Two scholarships are offered in 2018: One graduate school entrance scholarship of $5,000 and two undergraduate summer research scholarships of $3,000 each.

Graduate School Entrance Scholarship: $5,000

This entrance scholarship is designed to encourage undergraduate students to enter a graduate program related to Nuclear Science and Engineering at a Canadian university.

Eligibility

You must be currently enrolled in a full-time undergraduate program at a Canadian University and be a member of the CNS.

The duration of the graduate program must be such as to lead to a Master's or a PhD degree.

Undergraduate Student Research Scholarship: $3,000

This scholarship is designed to encourage undergraduate students to participate in research in Nuclear Science and Engineering during the summer months.

Eligibility

You must be enrolled in a full-time undergraduate program at a Canadian University for at least two years and be a member of the CNS.

The scholarship is to be matched by $2,000 from the student's supervisor for a total of $5,000.

The recipients of the scholarships will be selected on the basis of their academic standing and other information to be supplied with the application.

The Scholarship Committee of the Canadian Nuclear Society will collect and review the submissions, and make the award decisions.

Details of the scholarships and the procedure for application can be found on the CNS website at

www.cns-snc.ca/Scholarships

The deadline for submission of the application is **March 1, 2018**.

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Bourses en science et génie nucléaire dans les universités canadiennes

La Société Nucléaire Canadienne est heureuse d'offrir des bourses afin d'encourager les étudiants dans les universités canadiennes à étudier la science et le génie nucléaire.

Deux bourses sont offertes en 2018: une bourse de 5,000$ à l'entrée aux études supérieures, et deux bourses de recherche d'été (de 3,000$ chaque) pour étudiants poursuivant la licence.

Bourse d'entrée aux études supérieures : 5,000$

Le but de cette bourse est d'encourager les étudiants à s'inscrire aux études supérieures en science et génie nucléaire dans une université canadienne.

Éligibilité

L'étudiant(e) doit être présentement inscrit(e) plein-temps à un programme poursuivant la licence dans une université canadienne, et doit être membre de la SNC.

L'échéancier du programme en études supérieures doit être suffisant pour mener à une maîtrise ou à un doctorat.

Bourse de recherche pour étudiants poursuivant la licence : $3,000$

Le but de cette bourse est d'encourager les étudiants poursuivant la licence à participer en recherche en science et génie nucléaire pendant l'été.

Éligibilité

L'étudiant(e) doit être inscrit(e) plein-temps à un programme d'au moins 2 ans poursuivant la licence dans une université canadienne, et doit être membre de la SNC.

Cette bourse doit être complémentée par un montant de 2,000$ de la part du directeur de la recherche, pour un total de 5,000$.

Les gagnant(e)s des bourses seront sélectionné(e)s à partir de la qualité de leur dossier académique, ainsi que d'autres données à être fournies en même temps que la demande de bourse.

Le Comité des bourses de la Société Nucléaire Canadienne recevra et étudiera les candidatures, et attribuera les bourses.

Les détails des bourses et les procédures de demande sont disponibles sur le site web de la SNC à

www.cns-snc.ca/bourses

La date limite pour la soumission de demande de bourse est le **1er mars 2018**.

2017

October — **CANDU Fuel Technology Course**
Hilton Garden Inn Toronto/Ajax
Ajax, ON
cns-snc.ca/events

October 1-4 — **CANDU Maintenance & Nuclear Components Conference (CMNCC)**
Toronto Mariott Down
Eaton Centre Hotel
Toronto, ON
cns-snc.ca/events/cmncc-2017/

Fall — **CANDU Thermal Hydraulics Course**
Toronto, ON
cns-snc.ca

Nov. 12-16 — **2017 ANS Winter Meeting and Nuclear Technology Expo**
Washington, DC, USA
ans.org/meetings/c_1

2018

February — **CNA Nuclear Industry Conference and Tradeshow**
Westin Hotel
Ottawa, Ontario
cna.ca/2018-conference

March — **CANDU Technology & Safety Course**
cns-snc.ca

April 22-26 — **PHYSOR 2018**
Cancun, Mexico
physor2018.mx

May 2018 — **Nuclear 101**
cns-snc.ca

June 3-6 — **38th Annual CNS Conference & 42nd Annual CNS/CNA Student Conference**
Sheraton Cavalier Hotel
Saskatoon, SK
cns2018conference.org

June 17-21 — **ANS Annual Meeting**
Philadelphia, PA
ans.org/meetings

Sept. 30-Oct. 3 — **PBNC 2018**
San Francisco, CA, USA
pacificnuclear.net/pnc/pbnc
ans.org/meetings/c_2

Fall — **Waste Management, Decommissioning and Environment Restoration for Canada's Nuclear Activities**
cns.snc.ca

Fall — **International Conference on Simulation Methods in Nuclear Engineering**
cns-snc.ca

Fall — **International Technical Meeting on Small Reactors**
cns-snc.ca

Nov. 11-15 — **2018 ANS Winter Meeting**
Orlando, FL, USA

2019

February — **CNA Nuclear Industry Conference and Tradeshow**
Westin Hotel
Ottawa, Ontario
cna.ca/2019-conference

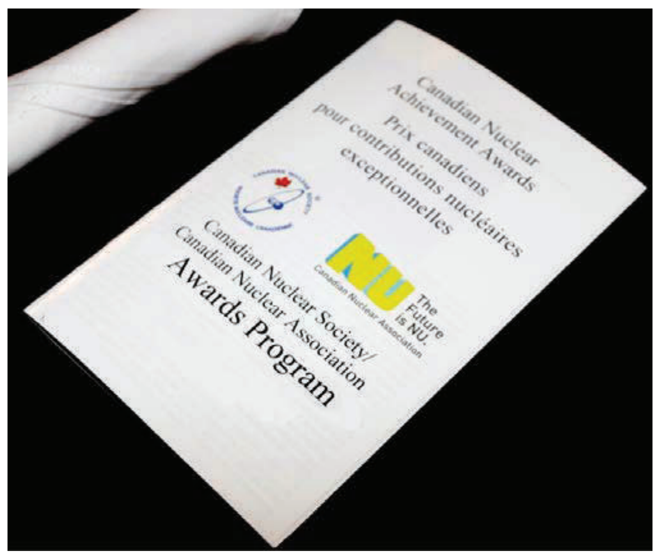
March — **CANDU Technology & Safety Course**
cns-snc.ca

May — **Nuclear 101**
cns-snc.ca

June — **39th Annual CNS Conference & 43rd Annual CNS/CNA Student Conference**
cns2019conference.org

2018 Canadian Nuclear Achievement Awards
Call for Nominations

We are announcing the Call for Nominations for the 2018 Canadian Nuclear Achievement Awards, jointly sponsored by the Canadian Nuclear Society (CNS) and the Canadian Nuclear Association (CNA). These Awards represent an opportunity to recognize individuals who have made significant contributions, technical and non-technical, to various aspects of nuclear science and technology in Canada.



Nominations may be submitted for any of the following Awards:

- W. B. Lewis Medal
- Ian McRae Award
- Harold A. Smith Outstanding Contribution Award
- Innovative Achievement Award
- John S. Hewitt Team Achievement Award
- Education and Communication Award
- George C. Laurence Award for Nuclear Safety
- Fellow of the Canadian Nuclear Society
- R. E. Jervis Award

The deadline to submit nominations is **January 19, 2018.** The Awards will be officially presented during the CNS Annual Conference held June 3 – 7, 2018 in Saskatoon, Saskatchewan, Canada.

For detailed information on the nomination package, Awards criteria, and how to submit the nomination please visit: http://cns-snc.ca/cns/awards.

If you have any questions, please contact Ruxandra Dranga, Chair – CNS/CNA Honours and Awards Committee by email at awards@cns-snc.ca, or by phone at (613) 717 – 2338.

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http://www.cns-snc.ca

Canadian Nuclear Laboratories | Laboratoires Nucléaires Canadiens

What is your vision for SMR technology in Canada. What role will you play in making this vision a reality?

www.CNL.ca/SMR

Canadian Nuclear Laboratories (CNL) has begun a process to explore the possibilities for Small Modular Reactor (SMR) deployment in Canada. As part of this effort we are gathering input from researchers, technology developers, nuclear supply chain members and interested community stakeholders.

Your participation through a short survey will help us identify the challenges and opportunities faced in bringing an SMR to successful deployment. We would like to have your input and invite you join the discussion at www.CNL.ca/SMR.

Submission deadline: July 31.