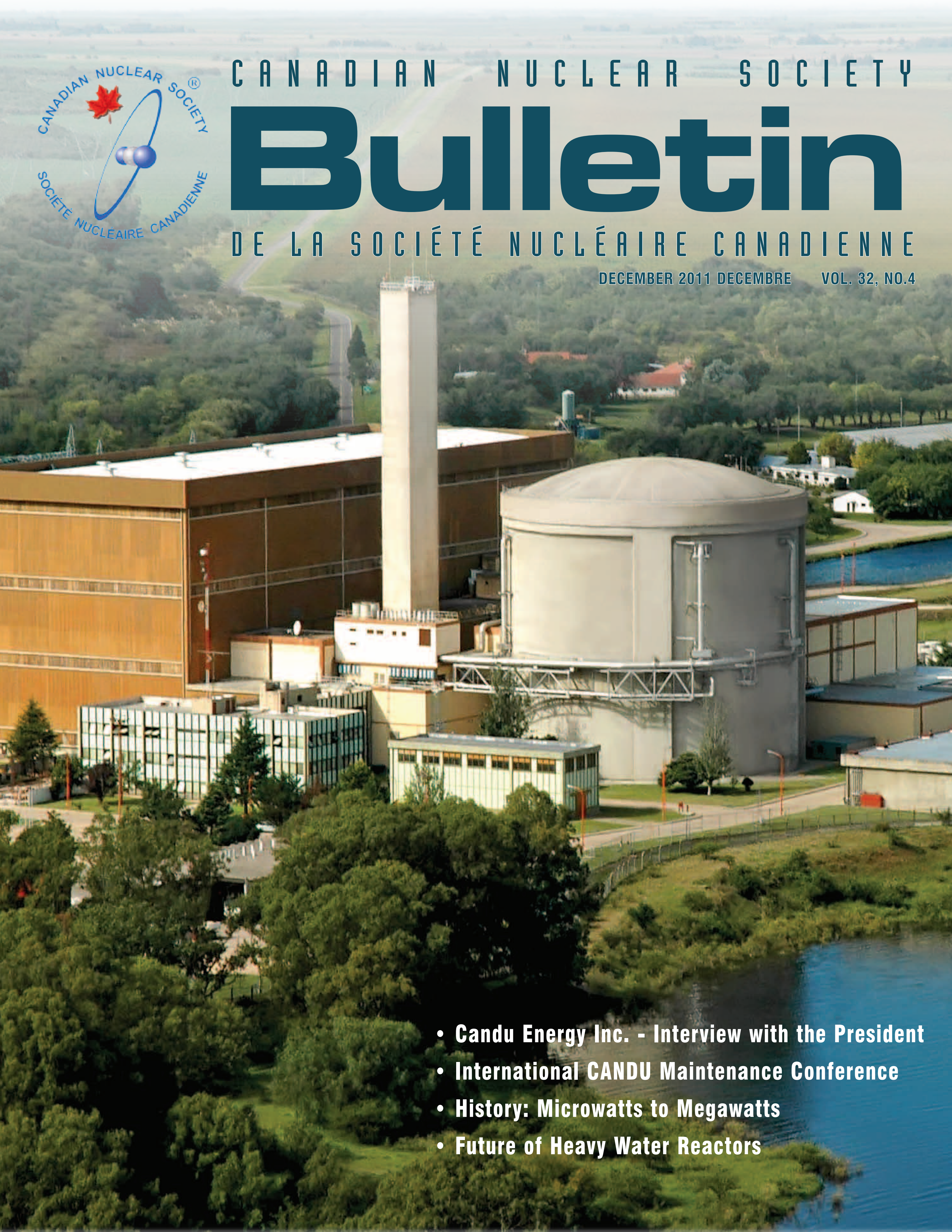
CANADIAN NUCLEAR SOCIETY

Bulletin

DE LA SOCIÉTÉ NUCLÉAIRE CANADIENNE

DECEMBER 2011 DECEMBRE VOL. 32, NO.4



- Candu Energy Inc. - Interview with the President
- International CANDU Maintenance Conference
- History: Microwatts to Megawatts
- Future of Heavy Water Reactors

Is Green the New Brown?

The Ontario Energy Board (OEB) was once responsible for ensuring that electricity production was both sustainable and reasonably priced. With the 2009 Green Energy Act, most of that responsibility is now with the government. According to the Auditor General's 2011 Annual Report, the government created a new process to expedite the development of renewable energy by providing the Minister with the authority to supersede many of the government's usual planning and regulatory oversight processes. Similarly, the Ontario Power Authority (OPA) was once responsible for the long term planning of the electricity system but the government, through the Green Energy Act, has taken over that authority. The energy plan issued by the OPA in 2007, called the Integrated Power Supply Plan (IPSP), was to be reviewed and approved by the OEB, but the government suspended the OEB review and directed the OPA to make the plan more "green". Then in November 2010, the "McGreen" government issued its own Long Term Energy Plan (LTEP) and directed the OPA to issue a revised IPSP in line with its LTEP, which includes nearly 20,000 MW of costly renewable energy by 2018.

The Auditor General's report states:

"Billions of dollars were committed to renewable energy without fully evaluating the impact, the trade-offs, and the alternatives through a comprehensive business-case analysis. Specifically, the OPA, the OEB, and the IESO acknowledged that no independent, objective, expert investigation had been done to examine the potential effects of renewable-energy policies on prices, job creation, and greenhouse gas emissions; and no thorough and professional cost/benefit analysis had been conducted to identify potentially cleaner, more economically productive, and cost-effective alternatives to renewable energy, such as energy imports and increased conservation."

The government proclaimed that the Green Energy Act would create 50,000 new jobs, but it did not say that most of these jobs would be for temporary construction, and that jobs would be lost in other sectors. In the UK, for example, four jobs are lost for every job created in renewable energy, primarily due to increasing electricity prices. Similar results have occurred in Spain, Germany and Denmark, and their "green" jobs require subsidies that mount to more than double the wages paid to those "green" workers.

The government claimed in 2009 that wind and solar would add 1% annually to the electricity bills, but in 2010 this was revised to 7.9%. Nevertheless, electricity bills increased by 26% and will increase by almost 50%. Facing an election, the government responded with a 10% reduction called the "Green Energy Benefit". Meanwhile, through its Feed-in-Tariff (FIT) program, wind and solar companies are paid double to quadruple the cost of conventional sources of electricity, and are even paid to NOT produce electricity when there is a surplus. The OPA recommended reducing the FIT pricing to be more in line with other jurisdictions but the McGreens refuse so as not to lose investor confidence in Green energy.

The OEB still regulates the price of nuclear and most hydro, but unregulated producers (wind and solar) are paid according to government policy, and this accounts for 65% of the electricity part of your monthly electricity bill.

Meanwhile the government has stalled on any decision for new nuclear build. Their argument about uncertainty with AECL is no longer valid. Pickering will reach end of life in less than ten years, and because wind and solar are unreliable and cannot produce when winds are too fast or too slow, there is a very real danger of brownouts in the province if new nuclear cannot come on line by then. The government is wasting time promoting its "Green" agenda.

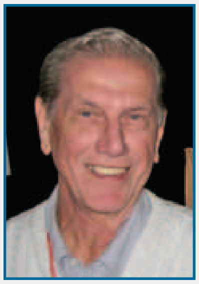
Green, it would appear, is the new Brown!

In This Issue

As of October 1 of this year the former commercial reactor division of AECL is now owned by **Candu Energy Inc.** President and General Manager **Kevin Wallace** kindly agreed to an interview with the CNS and provided an interesting insight into the future of his new company. We also have coverage of two conferences, the International CANDU Maintenance Conference and the Future of Heavy Water Reactors. On the topic of heavy water reactors, **Jim Arsenault** has compiled an interesting **history** of heavy water reactors, going from microwatts to megawatts in seven years beginning in 1939. And last but not least, **Jeremy Whitlock** explains the meaning of weak and strong in **Endpoint.**

In this last edition of 2011 I would like to take the opportunity to wish you all a happy and safe holiday and a productive new year!

From The Publisher



The Society

A significant recent activity of our Canadian Nuclear Society was the special gathering, called an "Officers' Seminar", held in Toronto over two days in late October.

The assembled group of members of the Council and representatives of Branches, Divisions and other activities numbered between 35 and 40 over the two days as a result of prior commitments of various participants.

As noted in the brief report in the CNS News section there were many positive proposals for improving and expanding Branch activities. In the view of many of us, this is vital for the continuation and expansion of the Society. Branches provide the opportunity for members to interact with their local comrades and participate in activities varying from presentations by interesting and knowledgeable individuals to helping with exhibits at science teachers' events or judging at science fairs. There is a commitment by Syed Zaidi, Council chair of Branch activities, and the several Branch Chairs present to move forward on these proposals.

Similarly, the discussion on Divisions, which have grown to eight in number, led to recommendations to merge some and develop more communication and, perhaps, coordination, between others. In the current structure of the Society, the Divisions are responsible for developing conferences focussing on their particular field. Not only do those gathering provide an opportunity for individuals to share knowledge and experience with their peers, those conferences are significant income generators for the Society.

A good example of the work of the Divisions was the *9th International Conference on CANDU Maintenance* held in Toronto the first week of December. It was another example of a small number of dedicated CNS members recruiting many non-members to participate.

However, the Officers' Seminar gathering did not really come to grips with the, in my view, most important topic – the restructuring of the governing organization of the Society and the recommendation, now several years old, to engage an Executive Director. In the view of many of us, the Society has survived too long on the great contributions of a small number of dedicated volunteers. While such volunteers will continue to be an essential component of an organization of individuals like the CNS, it has become evident to many that the business aspects and especially the promotion and expansion of the Society needs someone dedicated to those functions. There was an apparent consensus to move ahead on the ED matter which has been referred back to the Executive for implementation.

The Canadian Nuclear Scene

The past three months have seen a number of notable accomplishments, with possibly the most significant one being the formal turn-over of the engineering component of Atomic Energy of Canada Limited to SNC Lavalin and the creation of its sub-company Candu Energy Inc. Editor Ric Fluke's interview with Candu Energy's president, Kevin Wallace, featured in this issue, provides an interesting and encouraging insight into the transformation of that key component of the Canadian nuclear program.

Then, Bruce Power announced essentially the end of its reconstruction of Units 1 and 2 of the Bruce A plant with the refuelling of both. Start-up of Unit 2 is scheduled to occur in the first quarter of 2012. The early CANDU units were not designed for such an extensive refurbishment and all involved, the Bruce oversight team and the 2500 or so individuals from the 24 contractors, deserve much praise for their accomplishments.

Bruce Power has been exemplary in its provision of information about the refurbishment. As an example, its current website includes a video of the manual refuelling of Unit 2.

At the same time the long ordeal at Point Lepreau is approaching completion. All of the channels have finally been replaced, with refilling of the calandria underway and refuelling to follow early in the new year.

Unfortunately, there has been no progress on the political front on the new units to be built at the Darlington site. With OPG's earlier announcement of the shutdown of the Pickering units in 2020, time is running out. The Ontario premier appears mesmerized by the promises of the "environmental" movement.

The nuclear industry and the nuclear community as a whole have been woefully quiet while those representing solar and wind, in particular, have been very prominent and, apparently, successful in their promotion, which some of us would compare to propaganda.

Special note to CNS members

You should have received with this issue of the Bulletin a DVD about Ernest Rutherford. *It is one of a set of three produced by Dr. John Campbell of New Zealand who also wrote an excellent biography of Rutherford titled "Rutherford, Scientist Supreme. The enclosed DVD concentrates on Rutherford's work at McGill University at the beginning of the 20th century .The CNS was the only Canadian organization to sponsor the production of the DVDs.*

Also enclosed are three notices concerning bursaries or scholarships available to CNS members only.

Fred Boyd

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~ Cover Photo ~

View of Nucleoelectrica's Embalse CANDU station in Argentina.

Photo courtesy of Candu Energy Inc.

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ISSN 0714-7074

The *Bulletin of the Canadian Nuclear Society* is published four times a year by:
The Canadian Nuclear Society
655 Bay Street, 17th Floor
Toronto, Ontario, Canada, M5G 2K4
Telephone (416) 977-7620
Fax (416) 977-8131
e-mail: cns-snc@on.aibn.com

Le Bulletin SNC *est l'organe d'information de la Société Nucléaire Canadienne.*

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

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

Editor / Rédacteur
Ric Fluke Tel. (416) 592-4110
e-mail: richard.fluke@amec.com

Publisher
Fred Boyd Tel./Fax (613) 592-2256
e-mail: fboyd@sympatico.ca

Printed by The Vincent Press Ltd., Peterborough, ON

Canada Post Publication Agreement #1722751

MIX
Paper from responsible sources
FSC® C092694

Conversation with Kevin Wallace

by RIC FLUKE

Forward: Kevin Wallace is President and General Manager of Candu Energy Inc. which was formed on October 1, 2011 after the purchase of the commercial reactor division of AECL by SNC Lavalin. Kevin agreed to an interview with the CNS, which took place on December 9, 2011, at Sheridan Park in Mississauga.

CNS: Good afternoon Kevin.

KEVIN: Good afternoon to you Ric and I appreciate you taking the time to come out here.

CNS: You are an engineer and I find that to be very refreshing for the president of an engineering company, something that this organization hasn't seen for two decades – Dr. Stan Hatcher was the last president with a solid technical background. Could you talk about yourself and your experience particularly in the nuclear field?

KEVIN: My background, Ric, has been with SNC Lavalin for 16 years now. I actually started my career in the mining side and travelled internationally and extensively for about five years and came back to Toronto in late `98 or `99 and made the shift to our industrial energy power services side of SNC Lavalin. Shortly after that I took over the portfolio of energy now called energy infrastructure division which is responsible for thermal energy mandates, chemicals and processes for Ontario, Manitoba and Saskatchewan. We grew from what probably started as 100 people to about 1200 this previous summer. So we grew quite extensively and grew our revenue probably 10 times. During the process of the asset purchase agreement between SNC Lavalin and the Government of Canada and AECL, Patrick Lamarre who is our executive vice president, who by the way would agree with you that engineers are probably right lineage to manage technical issues, made a decision to put someone in charge of the new group on the asset purchase who has a long lineage of history within SNC Lavalin and had gone through the type of growth and developmental challenges that we're hoping Candu will have relative to the work opportunities we are looking for over the next three to five years. So on the energy profile I was responsible for all the work we did for Cameco – we had a relationship looking after all of Cameco fuel processing services so we had quite a bit of interfacing with the CNSC and also the Nuclear Waste Management Organization (NWMO). It was our division that did a lot of consulting and support for the NWMO as well. As far as the significant nuclear project experience... it hasn't been my lineage, but to be fair what we're looking for at Candu is really how we can benchmark within the nuclear world relative to what other industry concepts are doing with respect to large projects and work processes. A lot of what we are trying to do now is to really marry very strong technical competencies within the employment group that came over with the asset purchase agreement with strong business metrics and actually go into some significant benchmarking on how we

Kevin Wallace

President & General Manager

Kevin Wallace is President & General Manager of Candu Energy Inc. Candu is a full-service nuclear technology company with a team of 1,400 highly-skilled employees who design and deliver state-of-the-art CANDU® reactors, carry out life extension projects, provide plant life management programs and tools, and offer operation and maintenance services for existing nuclear power stations.

Prior to joining Candu, Kevin was Vice President and General Manager of SNC-Lavalin's Energy & Infrastructure Business Unit where he had overall responsibility for business operations in Ontario, Manitoba and Saskatchewan.

Kevin has over 15 years experience with SNC-Lavalin and has a strong background in project management, engineering, project controls, quality management and customer relations. He brings a strong record of successful delivery of projects and programs by building cohesive and motivated teams focused on quality, cost control, schedule adherence and customer satisfaction.

Kevin has a Mechanical Engineering degree from the University of Saskatchewan and a Masters in Business Administration from the Schulich School of Business in Toronto.

can actually see true process improvements for our execution of work.

CNS: This leads on to my next question which is your vision for Candu.

KEVIN: Being from SNC Lavalin, we wouldn't be as interested as we were in the AECL commercial reactor division unless we saw very significant business opportunities. While we've been very busy over the last three months going through the integration and repositioning, we're expecting significant growth over the next 3 to 5 years. Our expectations over the next five years is to double what our revenue stream will be for next year and that doesn't exclude what happens in Canada but a lot of our business metrics we're pursuing right now are really outside of North America. Even though we are strong proponents of Darlington New Build, to us that's not going to make or break Candu.

CNS: We will come back to that. It appears that SNC Lavalin still has a Nuclear division. Do you have plans to restructure or merge Candu and SNC Lavalin Nuclear or do you plan to use it as a separate entity?

KEVIN: That's a very fair question and is a question we get asked very often. The decision on that will definitely be to maintain two separate units so SNC Lavalin Nuclear will continue in their business focus of what they've been doing now for over 35 years. Candu is a much different business with a much different role and responsibility in the nuclear business. We will focus Candu on the niche technology operated as the original equipment manufacturer for all CANDU[1] utilities and provide the high-value intellectual support for any new build or life extension project. SNC Lavalin Nuclear, which is a very strong project management execution centre will maintain that focus. What we are looking at doing now is for significant new build opportunities or significant life extension projects – SNC Lavalin Nuclear will take the lead contracting role and we will work as a subcontractor being responsible for still very significant components of the work in the high-value technical services.

CNS: As far as I know Candu has not made a formal announcement since its formation - there have been news reports but has or will Candu be issuing a formal press release?

KEVIN: There was a formal press release in late June. The preliminary asset purchase agreement was signed in June with the vision of October 1 being the actual closing date so from the SNC Lavalin side we look to the late June 2011 announcement as being formal notice that an asset purchase agreement was signed, which to us was more important than the actual closing date. It is probably fair to say what with electoral activities and politics being what it was in October, making a press release just for the sake of making one was felt not to be required. So we quietly went about our business on October 1 and it was a Sunday and it was a very active day for us. At 8:00 am on Monday October 2 we were up and running as Candu Energy Inc. We are now working very hard to get organized and to match the cultures of the intrinsic organization here and to be a focused flexible effective organization. There was a lot of legacy noise in the marketplace relative to customer satisfaction and consistent delivery of work. Part of what we want to do is reassure our client base that we are focusing in hard on what our business line is and making sure that we can instil confidence in them that once we take on work we can deliver it. Most of what we touch as an organization is absolutely critical as you know from your background too, to how a utility operates and how a utility is successful and to not have confidence in an organization like us would really just rot away the underpinning of what we want to grow and become. A lot of our focus now is to make sure that we know we've got these skills competencies and effective procedures internally so that when we take on a mandate that we deliver it on time and on budget.

CNS: How are you branding the Candu name?

KEVIN: We were quite happy that, as part of the asset purchase, Natural Resources Canada did a lot of branding work before the actual sale was done and the Candu name drew into the actual company name. In some ways from a marketing perspective it was advantageous so we went with that because there is an immediate recognition relative to Candu Energy Inc. and the CANDU technology.

CNS: Is the engineering lab in SP3 a part of Candu?

Kevin: Yes. Since you know our campus here well, SP9, SP2, SP3, SP4 and soon SP5, which is one we are trying to get access to, will all be part of Candu Energy Inc. SP1 remains part of AECL. Part of what we are trying to do here is to get our work processes more effective and part of that is getting ourselves together and configuring ourselves more effectively from a functional perspective.

CNS: On the topic of labs, can you talk about your relationship with Chalk River?

KEVIN: That's a fair question and there is nothing

1 CANDU (in CAPS) is a registered trademark of AECL. Candu (lower case) is the newly formed Candu Energy Inc.

secret about that. Going forward we have a commercial arrangement with Chalk River so given the asset purchase agreement there was a very significant cultural change because the Chalk River Laboratories and Sheridan Park were one company and they had no transfer pricing mechanisms. What we now have is transfer pricing mechanisms with a commercial agreement on workflow because there is a lot of work that goes from here to Chalk River and a lot of work from Chalk River that comes here. There are commercial rates that are equitable and agreed to for the next five years. More importantly as part of the agreement we came up with Chalk River, we will act as the single point of contact for utilities. The marketing and business development division was always part of this group. What was formalized in the agreement is that we will represent Candu interest as well as the Chalk River Laboratories' interest and through the transfer pricing mechanism we will be their representative for utilities. If it is laboratory work it will just flow to Chalk River and if it's our work it will flow to us. If it is a combination we will manage it as project manager and the respective contributions will come from the two groups.

CNS: I presume then that Candu will be a supplier member of COG?

KEVIN: Correct. It's being worked out right now, so AECL will retain a more significant role in COG than Candu and Candu will act as a supplier vendor but won't be very active in the COG process. It is still a work in progress to get the refitted Candu within the right space in the COG organization.

CNS: What are your expectations for your relationship with the regulator, the CNSC?

KEVIN: Historically as part of SNC Lavalin Nuclear we have always been involved with the CNSC and we will keep that, probably in two fronts. The SNC Lavalin Nuclear group will interface with the CNSC but probably more of the interface will come from Candu. Part of the mandate in the asset purchase agreement is a mechanism to keep the development of the EC6 going forward. There are 24 design packages that we are proceeding which are highly involved with the CNSC relative to taking the EC6 design to a point where it is permitable for any utility.

CNS: Can you describe your ongoing relationship with the federal government, in terms of royalties and assistance that you might need in marketing?

KEVIN: Given the nature of nuclear we expect that we will continually be in close dialogue with the federal government especially from a policy perspective where we're going internationally. The government appears to be a clearer supporter of nuclear energy now than before given their perceived liabilities for the performance of the commercial reactor division on their balance sheet so we expect that we will keep a close relationship with them on a going forward basis. As you know there is a royalty payment stream relative to incremental reactor sales we would have for life extension projects which was probably more associated with the actual transaction on the asset purchase agreement more so than in a subsidy relative to the federal government.

CNS: So it would make sense for the federal government to assist if Candu wanted to sell a reactor in another country?

KEVIN: Well, part of the strategy on the asset purchase agreement was to make sure that all stakeholders were aligned relative to the success of Candu. If for some reason federal government woke up one day and said we're really not interested in anything to do with nuclear energy propagation nationally or internationally it would be very hard for us to run a successful business. Even as it is now when we travel internationally the feedback we get is when is the Darlington reactor going to be released, when are you going to start the refurbishment and re-tube efforts at Darlington ... as you know well the nuclear community is very small on the international scene and also the propagation of information is very thorough and it is always a significant market in other countries relative to our backyard so back to your question it was important for us in the asset purchase agreement to ensure that the government was going to be motivated for the success of us even though the royalty configuration to me is a very small component of how the federal government will benefit. A more significant pitch is the intellectual capital that we will development in Canada, the primary jobs the secondary and tertiary jobs relative to what the nuclear industry means to tax generation for the federal government and the provincial governments. We think that's a much more significant motivation for governments of all levels to be supportive of a successful nuclear industry.

CNS: It appears that the work on the ACR has been put on the shelf because there is no interest in Canada. Do you see any interest developing in other countries?

KEVIN: It is an interesting question. Right now as we sit, not particularly. I believe three or four years ago, when there was a high degree of motivation to develop ACR to a commercial level where it could be permitted, I think the world was in a different place relative to acceptance of new and improved reactor technology. I think a lot of what has transpired over the last two years with the predictability of design performance and operational performance has caused the nuclear world to be a lot more conservative in how they're looking at making significant investments, so we don't really have much for sales calls of people wanting to have the first of a kind, or wanting to tweak operational performance so that their operating cost is notionally better than what the incumbent reactors are – we have gone almost a 180° where proven is what everyone is looking for so most of the discussion we have on all fronts right now is much more towards the EC6 which has got a tremendous track record internationally as the regulars know well. So, for the time being our focus is on that front. As you know, if you are running a successful business we have to be aware of what our market pressures and market directions are going to go and so our marketing people are keeping very close to work where trends are going in the next three to five years. Right now as we sit there is nothing driving us to put a lot of R&D effort into the ACR.

CNS: There is a lot of uncertainty about new build at Darlington. Tom Mitchell said at the last CNA meeting that the next reactor will be an enhanced CANDU, but he didn't give it a number, fuelling speculation that OPG might prefer an enhanced CANDU 9, essentially an EC6 containment with an enhanced Darlington reactor inside. Can you comment on that?

KEVIN: The discussions we've had so far have been based on the EC6 technology and for me to speculate what the province of Ontario is going to do through Infrastructure Ontario is hard to say. We think there are probably some significant political gates to get over before we get into meaningful discussion. From our perspective, what we'd like to see is the government organize some pre-funding to get the design developed – land on the design, land on a strategy and then do enough pre-work that there's a higher degree of confidence in the actual execution schedule and the ultimate cost of the reactor unit. Infrastructure Ontario which is the engine that the Ontario government is using to proceed on that, in their world it is doing a lot of key infrastructure development whether it's in terms of hospitals, institutions, highway 407 extensions, etc. But a nuclear reactor as you can appreciate is a whole different animal than the hospitals they are currently building. They have a disposition to go to a template of how they operate and they would like you to give your best and final price to build a two reactors and take 100% liability and when you do that with very little work and it's a very big number then they say it's unacceptable. The reality is that to get to an acceptable number there is a reasonable appropriation of risk and a reasonable amount of work being done and an understanding of what's expected in local content. If the provincial government would like 80% Ontario content or 70% local content then we have to work towards that but the question is, is the government prepared to pay a premium to have that level of Ontario content? These are all important decisions that have to be made and understood from a political level before technically you can actually start doing a significant design and making a decision on execution. So, going forward on maybe a 10 to12 month pre-project release to the point where everyone is very aware of what the project is, what the metrics are and what it means to their respective stakeholder areas – we see that as very important for the government to make a smart decision. We're hoping that they will get to that point one day and recognize the importance of it. The other benefit is you would actually anchor the schedule right. All the back and forth as you can appreciate just keeps pushing out the start. Then the 7 or 8 year timing for overall project execution just keeps pushing out to the point where a lot of our energy challenges with Ontario continue to fester and actually gets worse because the nuclear option keeps moving out.

CNS: The recent announcement of the refurbishment of Embalse in Argentina came as very refreshing news for the industry and I'm sure very welcome news to Candu. However, your predecessor's performance with Point Lepreau left New Brunswick rate payers feeling way less than satisfied. Do you feel that to you have gained sufficient learning from that project and perhaps with Bruce as well that you will be successful in Argentina?

KEVIN: That's another question that we get asked very often. Point Lepreau was a very tough project and Bruce also had challenges. To be honest you could put all of the refurbishment projects in a category where all of them have experienced some sort of learning but not all have been as painful as the learning that occurred at the Point Lepreau project. Then you can appreciate as soon as information became available it was a very significant issue for us at SNC Lavalin to understand.

One of the core competencies within SNC Lavalin is risk management. We are far from being risk-averse but we have a very systematic way for how we analyze, develop work plans and something that's as close to the project managers as the contract is, if you manage risk you will have a successful project and if you don't, you're walking through the land mines. We are pretty confident relative to understanding what happened on the last three or four refurbishments to have a high degree of confidence relative to the Embalse project.

I think what was understood going into the Point

Lepreau project was two or three key issues but, to be fair, the construction team has done exceptionally well for the last four or five months, running ahead of schedule, productivity is good, the failure rates are below expectation so once the smoke cleared on Point Lepreau, and it was almost a year ago the decision was to regroup and dismantle the issues and re-start from scratch on the planned re-instalments. Progress is going well. Point Lepreau plant staff are pleased relative to the last six months and we're trending very well. So we think if we were to approach the Embalse project now relative to the lessons learned on how we are approaching it, we will be succesful and a lot of it is going into the Darlington refurbishment and re-tube and feeder replacement work as well. We have a higher degree of confidence on how to go about that work and actually execute it. And, to be fair, the Wolsong refurbishment went very well.

CNS: According to Nucleoelectrica Argentina (NASA), they expect to be re-tubing their reactor over a planned outage of 20 months. Can you be more specific about Candu's role in the project in terms of technology, tooling and expertise?

KEVIN: Right now the detailed design, work plans, all the tool design to support the refurbishment work is to be done by us. The construction will be managed by NASA themselves so we will send out a construction technician team to provide oversight and technical assistance during the entire process but the construction and installation work will be led by the Argentines themselves.

CNS: You mentioned the refurbishment of Darlington and I suppose Gentilly-2 if they are still interested.

KEVIN: Yes. Darlington's a little easier draw out on the radar than Gentilly. Hydro-Québec is still weighing its options. We've met with them several times and we think there's an appetite for them to proceed with that.

CNS: I don't think Québec really needs a reactor given their abundance of hydro, and really Gentilly-2 is more of a grid stabilizer than an energy source.

KEVIN: Well I was surprised to find out that nuclear makes up 2.5% of Hydro-Québec's capacity right now but with that being said it's still very important to the province of Québec and Réal Laporte [President of Hydro-Québec] told us that relative to them running a company it's very difficult because it's a very small part of their portfolio and it's a very risky piece of work to go through the refurbishment but he indicated that there was a tremendous appetite for the employment and job protection relative to that region of Québec. Therefore the comment was that there was a strong will to make the project proceed.

CNS: Moving on now to Romania, has Cernavoda expressed interest in completing units 3 and 4?

KEVIN: Yes, there is an active bid plan going on. We are responding to a Request for Proposal issued by Romania. We will submit bids for the build-out of Cernavoda 3 and 4 for the end of January. That's one of our key prospects for two new CANDU reactors.

CNS: Are they expecting a repeat of units 1 and 2 or something more enhanced?

KEVIN: It's unique in the way that when Cenavoda 1 and 2 were built the shell encasements were built for units 3 and 4. So the concrete structures have been there for 15 years. The trick for C3 and C4 will be to build within an existing CANDU shell and to meet all regulatory requirements for current protocols. It will not be at the same level of EC6 but will be a hybrid that our engineers refer to as a C6+. So it will be a unique offering. For us it's a fair bit of effort to provide them their proposal for C3 and C4 and the bid will be led by SNC Lavalin Nuclear while Candu Energy Inc. will be the technology supplier for all the high-value design.

CNS: Utilities have a lot of choice when they need a contractor with nuclear expertise and project delivery. What would you say are Candu's significant differentiators from the competition?

KEVIN: What I would say is that our biggest asset is the intellectual capital that we have within Candu. We've got a tremendous competency of personnel. I was thoroughly impressed with the average tenure of our senior engineers, scientists and technicians within the organization and the amount of experience they've had on many of the reactor builds which historically has been very key for AECL. A lot of customers I talk with are highly complimentary of the talented personnel we have relative to their intellectual capacity to solve problems and to be proactive on solutions. So it goes back to what I said earlier – we want to work very hard to protect that and put that into an envelope where we would have solid project management skills, solid execution talent and to bring in good procurement skills such that we can build on that respect with the Candu group and then be able to harvest that in a very consistent and dependable manner for our cliental. There have been lots of positives and areas of improvement that we've earned and so we want to protect that, grow and actually have a flexible proactive organization that can respond to the utilities needs.

CNS: Candu is a unionized workforce. What are your expectations regarding your ongoing relationships with the unions?

KEVIN: It's intrinsic with what AECL was. We have three collective agreements that came over with Candu and these have expired. Our vision is to re-negotiate those three collective agreements.

CNS: I assume that Candu is a member of the CNA?

KEVIN: Correct.

CNS: The CNA is an organization of corporations, whereas the CNS is an organization of individuals. Will Candu be encouraging its employees to participate in CNS activities?

KEVIN: We do have a town hall coming up on Monday and it's interesting that you bring that up. This morning at the CNA I met the leader of Women in Nuclear and there was supposed to be a CNS presentation this morning. To answer your question differently, to me it's very important to engineers to be very active in associations so my message to employees on Monday will be to continue a high level of activity on that. Traditionally, we have been very active in the CNA and the CNS relative to interfacing on many fronts. You [CNS] are a very well respected organization.

CNS: On the topic of town hall meetings, I attended one here while seconded to AECL and it was just after the Province of Ontario announcement that Family Day would be a provincial holiday. The town hall was organized to allow employees to ask CEO Hugh MacDiarmid questions on important topics like the future of MAPLE and ACR, but the topic that dominated the discussion was would AECL be getting Family Day?

KEVIN: Well if it comes up again the answer is simple. We are part of the SNC Lavalin family and yes it is a statutory holiday. But that goes back to your question about the collective agreements. The union is something a little different to us. We want to respect them as a partner and we need to get to being a flexible organization. For example SNC Lavalin in Canada has a program of 'earned days off' so employees can work an extra half hour or so and take time off later. We have a lot more flexibility on how we organize ourselves and this is something we got a lot of good feedback from employees. But given the collective agreement it's not so easy to wake up one morning and say "You know, we're going to have an 'earned day off' program so you can bank an extra half hour a day and take days off or have some extra time at Christmas." It becomes very challenging to get little things like that through.

We want to meet with the representatives of the bargaining units and I'm hopeful we will come to something that is going to benefit the union group in a very positive way. To deploy people to places like Point Lepreau it's extremely difficult relative to what the collective agreements say, yet the last thing I want to do is to get into a situation where we feel compelled to subcontract work because we can't develop the talent internally and use that talent any place outside of Mississauga. To me that could deter our ability to grow a successful company because we want to have those skills incumbent inside us and we can continue to grow in the long lineage of experience. At the same time we have to be competitive and to your other question about what are we going to tell utilities to entice them that we're the right choice- we need to say that we are efficient, we are flexible, we can solve their problems in a timely and responsible way.

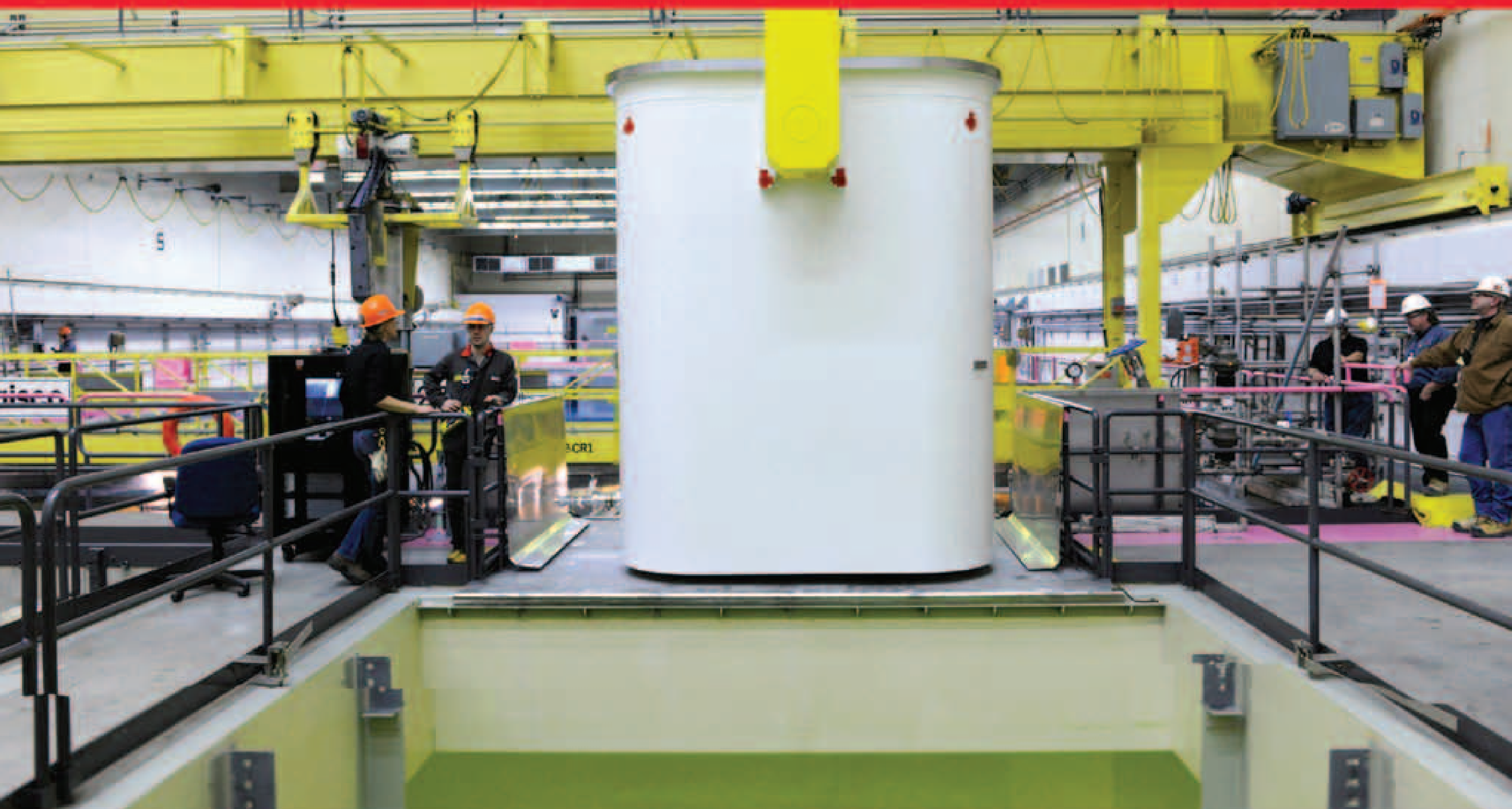
CNS: Is there anything else that you would like to say to CNS members?

KEVIN: I'd like to recap on your very first comment – SNC Lavalin in buying the commercial reactor division from Natural Resources Canada, we see a high degree of value in that asset set and our expectation is that we will work very hard to improve our business metrics.We expect to grow very significantly in the future. At the highest levels of SNC Lavalin, we are going to work very hard to make sure that the nuclear industry in Canada continues to propagate and grow and continue to be recognized as they are in the international market place.

CNS: Once again I'd like to say that it's good to have an engineer in charge of this nuclear engineering company.

KEVIN: Well I'm fascinated with that comment because in the SNC Lavalin world, except for finance, anyone who leads a product line is always an engineer. When I decided to make the decision to go into engineering or business I had more attributes towards business but someone told me that if you actually follow a business line it is hard to grow respect relative to the technical side whereas if you actually spend the time in the technical field, over time it will complement the business side to shore it up and you can still carry yourself competently as a business person.

CNS: Thank you Kevin and I'm sure the nuclear industry in Canada welcomes Candu Energy Inc. and on behalf of the CNS I wish you every success.



9th CNS International Conference on CANDU Maintenance

CANDU Maintenance Conference takes modified approach

by Fred Boyd

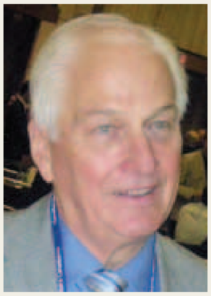
Over 400 delegates, representing most of the operating CANDU plants, converged on the Convention Centre in downtown Toronto, December 5 and 6, 2011 for the ninth version of the *CNS International CANDU Maintenance Conference.*

About half of the delegates arrived in time to partake of the opening reception on the Sunday evening, December 4.

A modified approach that had been advertised was primarily in the structure of the plenary sessions. First, there were four plenary sessions, morning and afternoon each day, with only two speakers at all but one. Then, in an attempt to focus the open discussion period, "Terms of Reference" (key points) were presented by one of the conference organizers before inviting questions from the floor. (Despite this admirable objective, many of the questions strayed from the prepared script.)

Given its popularity at the last Maintenance Conference, a *CANDU Configuration Overview Course w*as presented on the morning. This required pre-registration and was totally subscribed early in the conference.

Those attending the opening reception were met with a novel arrangement of the large hall, with tables set up in the middle and exhibitors divided into two groups at each end of the room. A debate continued throughout the conference on the effectiveness of this arrangement. The tables remained during the plenary sessions. Technical sessions were held in "break-out" rooms.



At the opening reception, **Bill Schneider**, Executive Chair (and primary mover of the conference) greeted those present and introduced **Jacques Plourde**, Conference General Chair. Plourde emphasized that the forum was an opportunity to share experiences and suggested a focus on processes to achieve reliability. Experiences of the past can lead to a more successful future, he commented, noting that the conference covered a wide scope, from periodic outages to major refurbishments.

Plourde then introduced **Wayne Robbins**, Chief Nuclear Officer, Ontario Power Generation, who began by saying that their challenge is to be the best in the world. The Ontario electricity supply will be extensively revitalized over the next few years, he predicted, with reference to the Environmental Assessment for new units at Darlington and contracts already issued for retubing of the existing units. After noting the questions arising from the Fukushima event, he closed by urging delegates to have an open and honest dialogue on improving performance.

Mike Gabbani, of, GE Hitachi Nuclear Canada, the sponsors of the reception, spoke briefly about the long history of his organization going back to the involvement of Canadian General Electric with NPD and Kanupp. His company is optimistic and continuing to invest. Politicians cannot ignore reality forever, he commented in closing.

Frank Doyle, president of the Canadian Nuclear Society, noted that 2012 will be the decennial anniversary of a number of notable events such as the creation of Atomic Energy of Canada Limited in 1952 and the start-up of the first CANDU, NPD, in 1962. These will be high-lighted at the CNS Annual Conference next June in Saskatoon. On behalf of the Society he welcomed participants from across Canada and abroad and thanked the organizing team and sponsors,

On the Monday morning, Jacques Plourde opened the conference promptly at 7:55 a.m.! He reminded delegates of the focus of the conference – NIOU – Needs and Interests of the Operating Utilities.

The first plenary session, titled *Tightly-Managed Outage and Operating Services*, was co-chaired by **Gary Roland** of Bruce Power and **Rob Adams** of Candu Energy.

The first speaker was **Marlene Ramphal**, Manager, WANO Peer Review, Ontario Power Generation, on the topic *World Class Performance: the Outage / Operating Cycle Continuum.* Darlington is on a journey of excellence, she stated, to be the best performing nuclear station in the world and outage excellence leads to world-class performance. She stated three "Ps": People, Process, Plant. Everyone involved in an outage needs to have common goals, she emphasized. The aim is to reduce 60 day outages to 40 days, she noted in closing.

Len Clewett, Vice-President, Nuclear Maintenance Services, Bruce Power, was the second speaker at this opening plenary. His topic was *Outage Improvement*

Initiative at Bruce Power. They have initiated a "35 / 30 Outage Improvement Project" with a target of attaining an outage length of 35 days on a schedule of every 30 months. They have 12 teams with a total of 200 members working on methodology applied to six major projects.

Before opening the session for questions, Jacques Plourde stated that the objectives of the conference were: improve performance; identify areas for improvement; minimize forced outages; minimize the distraction of new reactors.

In the discussion period Clewett commented that Bruce is looking at doing more internally rather than using contractors. Gary Roland then noted that a recent spate of retirements led him to hire a smaller number of young, relatively recent, graduates, who fulfilled the tasks and came up with improvements.

To have a record of the discussions, the conference organizers had recruited a number of students whose task was to corner the questioner with a form to write down their question, then gather all of these and pass them to the speaker involved to record their reply. The intention is to have all of the open discussion recorded on the conference CD which will be available from the CNS office in a month or two.

Following a mid-morning break, delegates then divided to attend one of the parallel technical sessions. This pattern continued for the two days of the conference. The subject titles for the Monday morning technical sessions were:

- Industry Performance Special Session
- Chemistry / Dose Control
- Learning from OPEX

After an extended lunch break, to give delegates time to visit the exhibits, the second plenary session took place on the topic *Essential Tools for Competent Performance,* with co-chairs **Bob Morrison**, President of CANDU Owners Group, and **Sean Bagshaw**, consultant.

Michael Binder, President, Canadian Nuclear Safety Commission, led off with a presentation on the *Regulatory Perspective.* He began by referring to the CNSC's extensive response to the Fukushima incident and stated that the Commission will hold a public hearing on the event and the CNSC actions in February 2012. He noted how Fukushima had put an unfavourable spotlight on nuclear resulting in public support waning.

Binder listed a number of topics high-lighted by Fukushima, such as: extreme natural hazards; beyond design basis accidents; station blackouts; loss of heat sinks; emergency planning; and, for the CNSC, the regulatory framework. In closing he commented that good performance of operating plants goes well beyond maintenance. *(Binder's presentation is available on the CNSC website.)*

The second speaker was **Gary Newman**, Chief Engineer and Vice-President Engineering, at Bruce Power, who spoke on *Canada's Response to Fukushima.* He commented that much of his talk would be based on a recent meeting of WANO (World Association of Nuclear Operators). In parallel with the CNSC action, WANO requested all CANDU utilities to document their ability to deal with "beyond design basis" events. Some of the conclusions of the reviews were: protect the fuel; keep water in the boilers; have additional portable power supplies; create emergency equipment warehouses.

On emergency response, he echoed a comment that Binder had made about the multiple jurisdictions involved (municipal, provincial, federal). He stated that EMO (Emergency Measures Ontario) is reviewing its nuclear response capabilities.

In the question period Binder was asked about the negative perceptions of radiation arising from the adoption by all nuclear regulatory agencies of the LNT (linear, no-threshold) theory of radiation effects in setting dose limits. He responded that this is embedded in law in most countries and laws are difficult to change. He added that it will be necessary to get the medical community "on board" to effect a change.

The concurrent technical sessions on the Monday afternoon were titled:

- Industry Performance Special Session
- Getting it right
- Inspection tools

That evening the conference dinner was held with guest speaker **Bob McDonald**, host of the CBC radio program, *Quirks and Quarks.* For close to an hour he engaged his audience with visions of our planet, enhanced by several views of earth taken from space. He showed video clips of his mock "space" trip on an airplane that manoeuvered to create a short period of weightlessness. He urged the audience to talk with children. They can engineer the way to the future, he commented in closing.

Tuesday morning began with a plenary session on *Refurb-ishments Small and Large* with co-chairs **Claude Drouin**, of Gentilly -2 , Hydro Québec, and **Yung Hoang**, of AMEC NSS. This plenary session had three presentations.

Frank Guglielmi, Director, Operations and Maintenance, Darlington Refurbishment, OPG, led off with a presentation on *Scope Selection and Control*. For the Darlington refurbishment the Objectives are: an additional 30 year life; meet regulatory requirements; make safety improvements. These targets will be posted to remind all involved. Selection criteria include: regulatory requirements, life-limiting systems and components and sustainability. The scope size will depend on risk ranking and benefit analyses.

Although the decision on the refurbishment of Gentilly 2 has been deferred, **Claude Drouin** reviewed its history and status. The refurbishment was first approved (by HQ) in 2008, then put on hold in 2010, partially because of the experience of Point Lepreau. In November 2011 the government said there would not be a decision until the spring of 2012. Nevertheless further planning is underway on defueling, decontamination and other topics. A new safety study is scheduled to be completed in the fall of 2012.

Rounding out the session, **John Soini**, Vice-President, Restart Projects and Construction, Bruce Power, spoke about the extensive refurbishment of units 1 and 2 of the Bruce A plant. He noted that this huge project is nearly complete with refuelling underway at the time of speaking. This was a first of a kind operation which involved 24 contractors with 2,500 contract personnel. As well as a complete retubing of both reactors there was extensive refurbishment of the balance of plant.

On restart, he commented it was not primarily a technical problem but an organizational one. The refurbishment exercise was set up with a separate organization and the units now will be turned over the operations group. There is the potential for further refurbishment, he commented in closing.

When asked about the choice between building new and refurbishment, Soini stated that, although refurbishment is very difficult there is a cost saving. Both he and Guglielmi commented that it is essential that all of the various contractors have the same high quality standards.

There were just two technical sessions on the Tuesday morning:

- Industry Performance
- Fitness for Service

The change was to allow for the all-morning "CANDU Configuration Overview Course" designed to give new employees an insight of the entire design of a typical CANDU nuclear power plant. This had been offered at the last CANDU Maintenance conference and was so popular it was repeated, requiring pre-registration. The limit of 100 attendees was met early on the first day of the conference.

The final plenary session had the unwieldy title of *Issue-Resolved, Configuration Managed, Replication – New-Build 2011 – Style*, the co-chairs were: **Mark Elliott**, Senior Vice President Nuclear Engineering and Chief Nuclear Engineer, OPG, and **Ron Oberth**, President, Organization of CANDU Industries.

Mark Elliott was also the first speaker with a presentation titled *OPG's Plan for Nuclear Projects: the "Engineer, Procure, Construct" Model.* This concept involves contractors being involved with approximately half of each of the stages. It is desirable, he said, to have constructors involved at the design stage.

The concept was tested with a modest-scaled project at Pickering B, he said. That experience led to the selection of a small number of EPC vendors all of whom would use OPG's administration and approval processes. Contracting out procurement is taking the most work to define, he said, as OPG has never out-sourced that function. OPG believes EPC is a "break-through" strategy, he said in said in closing.

The second presentation was by **Mike Soulard,** Director Enhanced CANDU 6 Project, Candu Energy Inc. whose title was *EC6 for Darlington as a Managed-Enhancements Replication Project.*

EC6 is designed for a target lifetime capacity factor of 92 %, based on 94% year-to-year and a 1 % forced loss rate. Achieving short maintenance outages of less than a month once every 36 months is a key target. He listed a number of enhancements designed to improve performance and facilitate maintenance. These include: improved material and chemistry specifications; advanced computer control systems for monitoring and display; a maintenance based design strategy; and more. The target life is 60 years with one mid-life refurbishment. All life-limiting factors have been evaluated and addressed, he added.

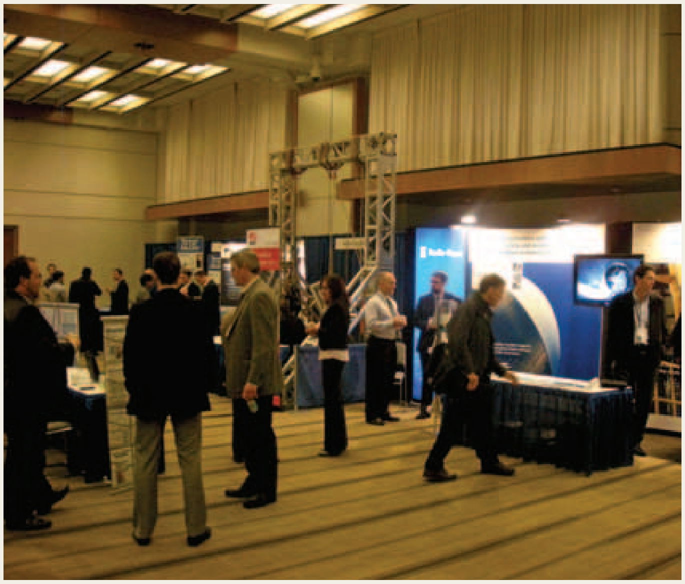
The final set of technical sessions was:

- Industry Performance
- Refurbishment and Beyond
- Advanced \instrumentation and Control Systems for CANDU Refurbishment
- Service Provider Improvements

The conference was organized and run by a large team of volunteers. Jacques Plourde was General Chair while Bill Schneider was Executive Chair and primary organizer. Ken Belfall served as treasurer. Other members of the organizing team were: John Roberts; Peter King; James Smith; Peter Angell; Jurus Grava; Mohinder Grover; Marc Paiment; Ai Tanaka; Vinod Chugh. Graham MacDonald developed and presented the CANDU Configuration Overview Course. A student sponsorship program was run by: Revi Kizhatil; Kale Stallaert; and Paul Hammell. Sponsorship sales were handled by Martyn Wash and Mark Toffolon; while Simon Weston and Kevin Wolf looked after exhibit space sales. Elizabeth Muckle-Jeffs handled all of the administration tasks, except registration which was done by Bob O'Sullivan and Denise Rouben of the CNS office. The conference was authorized and sponsored by the Canadian Nuclear Society.

A CD of the presentations and discussions will be available from the CNS office in early 2012.

Scenes from the Conference



International Conference on Future of Heavy Water Reactors: Towards Sustainability

Prepared by LAURENCE LEUNG

Many of the world's nations believe that a greater use of nuclear energy will be required to achieve sustainable emissions-free energy production and energy use while economically meeting the requirements of security of supply (energy independence) and growing demand. Heavy Water Reactor (HWR) technology is uniquely suited to respond to the future needs because of its inherent technical characteristics and associated fuel cycle flexibility.

The Canadian Nuclear Society (CNS), with the support of the International Atomic Energy Agency (IAEA) and other international nuclear societies, organized the first International Conference on HWR Future on 2011 October 3-5 at the Marriott Hotel in Ottawa, Ontario, Canada. It kicked off the conference with a reception on October 2 for Canadian and international delegates to introduce themselves. The reception was held at the top floor of the Marriott Hotel, which rotated and provided a 360° view of Canada's national capital to the delegates.

A total of 120 registered attendants from eight different countries participated in the conference. Mr. Jonathan Will, Director General of Electricity Resources Branch in the Energy Sector of Natural Resources Canada, welcomed the delegates and provided a brief summary of the nuclear energy situation in Canada. Four distinguished speakers, from Candu Energy Inc., Atomic Energy of Canada Limited, Natural Resources Canada, and the IAEA, presented the keynote speeches. They covered respectively the latest development of the Enhanced CANDU-6 Reactor, the R&D capability to advance HWR technology, a walk-through from the start-up of the NRX research reactor in Chalk River to the Generation-IV Supercritical-Water-Cooled Reactor, and the HWR-related activities at IAEA.

After the motivating presentations from the keynote speakers, the delegates dispersed to two parallel sessions. A total of 56 presentations and two panel discussions were scheduled over two and a half days, covering various HWR technology areas including important topics such as enhanced safety capabilities, regulation, advanced fuel cycles (such as thorium), and future heavy-water-reactor directions and concepts. Each session was well-attended and only standing room was available in some sessions. While the main objective of the conference was to share information on advances and development of heavy water reactors, many opportunities were provided to attendants during lunches and breaks for one-to-one and small-group discussions fostering future collaborations. The conference banquet was arranged on the evening of October 4. Frank Doyle, President of the CNS, was the guest speaker; he identified various key events of the HWR development in Canada and shared his views on the future HWR development and the direction of the CNS.

The conference was successfully concluded on October 5. The success of the conference has been attributed to the hard work of the organizing committee (which included Bob Speranzini, Romney Duffey, Peter Purdy and Ben Rouben), Denise Rouben and Bob O'Sullivan of the CNS Office, and Caroline Rouben of Spot Media. The organizing committee appreciated the financial support from Candu Energy Inc., Atomic Energy of Canada Limited, the Government of Canada, and Isowater Corporation.

A technical tour of Chalk River Laboratories at Atomic Energy of Canada Limited was organized on October 6. Participating delegates left the Marriott Hotel early in the morning and were driven through the scenic route of the Ottawa valley to enjoy the beautiful fall color. They were greeted by Rick Didsbury, who provided an overview of the laboratories, and visited the ZED-II Reactor, thermalhydraulics test facilities, hydrogen technologies laboratory, and the Inspection, Monitoring and Dynamics Laboratory. In view of the time limitation, the delegates were invited to return and tour other facilities in the Laboratories.

Future of HWR Conference – An Observer's Viewpoint

by Fred Boyd

Since primary organizer Laurence Leung has prepared a summary of the Future of Heavy Water Reactors Conference *the following note is intended to augment his report and offer some comments from a long-time participant and observer of the Canadian nuclear scene.*

Despite, or perhaps because of, the wide scope of the *Future of Heavy Water Reactors Conference*, the beginning of November 2011, the attendance was lower than at the two other CNS sponsored conferences held the previous month: the long-titled *Waste Management, Decommissioning and Environmental Restoration for Canada's Nuclear Activities;* and *NURETH, the 14th International Topical Meeting on Nuclear Reactor Thermalhuydraulics* (see the September 2011 issue – Vol. 32, No. 3 of the CNS Bulletin) It could also be that the HWR event was held in Ottawa, which is only the nation's capital, while the other two were in that "great" metropolis of Toronto.

As outlined by Laurence, the HWR conference did provide both an overview of the features and advantages of the CANDU concept and some excellent papers on various aspects of the technology. He and his colleagues deserve praise for organizing and running a very good conference.

The opening plenary was especially interesting for those seeking an overview of the HWR (read CANDU) concept, its current status and potential future. There were four presentations.

- *Future of Heavy Water Reactors – a Perspective* by Jerry Hopwood, Candu Energy Inc.
- *AECL Nuclear Laboratories – Continuing the Path of Science and Technology Innovations* by Bill Kupferschimidt, Atomic Energy of Canada Limited
- *IAEA Program to Support HWR Technology Development* by Jong Ho Choi, International Atomic Energy Agency
- *Canadian Gen-IV Heavy Water Development Program* by Daniel Brady, Natural Resources Canada

The remaining two and a half days were devoted to technical sessions and two panel discussions.

The technical presentations were grouped under the following headings:

- Reactor Design
- HWR Technology
- Physics and Neutronics
- Thermalhydraulics
- Advanced fuel Cycles
- Refurbishment
- Thorium Fuel
- Transmutation
- Super-Critical Water-Cooled Reactors
- Tritium and Moderator-related Studies
- Safety Analysis
- Heavy Water Technology
- Fuel and Fuel Safety

The two panel discussions were on:

- Current Developments and Challenges in Heavy Water Reactor Physics Analyses
- Fuel CHF Enhancement Technologies to Improve Safety Margins, Enhance Power Output and Mitigate Ageing Effects.

As an observer I had expected, from the title, that there would be some inclusion about the non-technical constraints on expanding the role of CANDU type reactors, such as financial, political, safeguards, unit size, maintainability, etc. To me, these factors can be just or more important as the technology in a nation's or utility's choice of a nuclear power plant.

Nevertheless, this was a well-organized, well-run event and presented many very good technical papers. They are all available on the conference CD which is available through the CNS office.

IAEA Programme To Support HWR Technology Development

by J. CHOI[1]

[Ed. Note: The following paper was presented at the "International Conference on Future of Heavy Water Reactors: Towards Sustainability" held on October 3-5, 2011, in Ottawa, Ontario, Canada.]

Abstract

The International Atomic Energy Agency (IAEA) works with its Member States and multiple partners worldwide to promote safe, secure and peaceful nuclear technologies. To catalyse innovation in nuclear power technology in Member States, the IAEA coordinates cooperative research, promotes information exchange, and analyses technical data and results, with a focus on reducing capital costs and construction periods while further improving performance, safety and proliferation resistance. This paper summarizes the recent IAEA programme to support technology development for heavy water reactors.

1. Introduction

Heavy Water Reactors (HWRs) are the second most common type of nuclear reactor installations in the world, second only to Light Water Reactors (LWRs). At present 47 HWRs are operating in 7 countries and 3 HWRs are under construction.

The IAEA programme on HWR is planned and implemented with the advice and support from the Technical Working Group on Advanced Technologies for Heavy Water Reactors (TWG-HWR), which is composed of IAEA Member States with operating or planning HWRs.

The mission of the IAEA Division of Nuclear Power is to increase the capability of interested Member States to establish/develop, implement and maintain competitive and sustainable nuclear power programmes and to develop and apply advanced nuclear technologies. The IAEA frames to support the development and the application of HWR technologies includes:

- Coordinated Research Projects (CRP)
- International Collaborative Standard Problems (ICSP)
- Technical Meetings (TM)
- International Collaborative Assessments (ICA)
- Training Courses and Workshops.

This paper summarizes the major recent and ongoing IAEA activities and publications to support HWR technology development.

2. Technical meetings and publications

Many design organizations have been developing advanced water cooled reactors. To provide IAEA Member States with the state-of-the-art information on advanced reactor designs, the IAEA has been periodically issuing status reports based on the technical information collected from the designers [1-4]. These documents present an overview of development trends and goals, as well as detailed descriptions of advanced water cooled reactor designs according to a common outline. The descriptions include summaries of measures taken by the designers to enhance economics and maintainability. Especially TRS-407 [2] is a text book for HWRs including evolution, characteristics, fuel cycles and safety aspects.

Advanced applications of nuclear energy include seawater desalination, district heating, heat for industrial processes, and electricity and heat for hydrogen production. In addition, in the transportation sector, since nuclear electricity is generally produced in a base load mode at stable prices, there is considerable near-term potential for nuclear power to contribute as a carbon-free source of electricity for charging electric and plug-in hybrid vehicles. IAEA-TECDOC-1584 [5] examines the potential of nuclear energy to expand into these markets by presenting an overview of sample applications, their opportunities, challenges and solutions.

The task on "Optimizing Technology, Safety and Economics of Water-Cooled Reactors" was carried out during 1999-2002. Its objective was to emphasize the need, and to identify approaches, for new nuclear plants with water-cooled reactors to achieve economic competitiveness while maintaining high levels of safety. To achieve the largest possible cost reductions, proven means for reducing costs must be fully utilized, and new approaches (such as improved technologies, risk informed methods for evaluating the safety benefit of design features, and international consensus regarding safety requirements so that standardized designs can be built in several countries without major re-design efforts) should be developed and implemented [6].

The pressure tubes of HWRs operate in a high-temperature high-pressure aqueous environment and are subjected to fast neutron irradiation. In order to ensure the PT integrity at all times during their service, they are periodically examined by Non-Destructive Examination (NDE) techniques. The IAEA conducted

1 International Atomic Energy Agency, Vienna, Austria

a CRP on inter-comparison of techniques for HWR pressure tube inspection and diagnostics. The intent was to identify the most effective pressure tube inspection and diagnostic methods, and to identify further development needs. The CRP was conducted in a round-Ðrobin manner. The participating laboratories prepared pressure tube samples containing artificial flaws/blisters/hydrogen resembling real defects of concern. The outside surface of sample was covered to facilitate blind testing. The samples, after examination by participating laboratories, were returned to the originating laboratory, which determined 'defect truth' in its sample. The originating laboratory analysed the sample inspection reports from investigating laboratories and compared the defect estimates with their true values. The CRP was conducted in two phases, the first one focused on flaw detection and characterization and the second one dedicated to the ddetermination of hydrogen concentration and blister characterization [7-8].

The value and importance of organizations engaged in the nuclear industry collecting and analysing operating experiences and best practices has been clearly identified in various IAEA documents and exercises. Both facility safety and operational efficiency can benefit from such information sharing. Such sharing also benefits organizations engaged in the development of new nuclear power plants, as it provides information to assist in optimizing designs to deliver improved safety and power-generation performance. In cooperation with Atomic Energy of Canada, Limited, the IAEA organized the Workshop on Best Practices in Heavy Water Reactor Operation in Toronto, Canada in September 2008, to assist interested Member States in sharing best practices and to provide a forum for the exchange of information among participating nuclear professionals. The papers presented at the workshop were published as an IAEA technical document [9]. Korea Hydro and Nuclear Power Co., Ltd (KHNP) hosted the second workshop on "Good Practices in HWR Operation" in Gyeongju, Rep. of Korea in April 2011.

3. Coordinated research projects

3.1 Benchmarking severe accident computer codes for HWR applications

Currently different countries follow different regulatory requirements for severe accident considerations in HWRs. It is expected that the new reactor projects will explicitly and systematically consider severe accidents during the design phase to minimize the likelihood of severe core damage and large radioactivity releases.

Computer codes used for the analysis of design basis events have been validated against integral and/or separate effects tests, whereas in the case of severe accident computer codes it is rather impossible, or at least quite expensive, to carry out a validation exercise against integrated experiments. Consequently, the code capabilities have to be assessed based on benchmarking against other severe accident computer codes. In view of this, a benchmarking exercise becomes necessary to assess the results from various computer codes to provide an improved understanding of modelling approaches, strengths and limitations. The exercise could also suggest ways to overcome code limitations and thereby increase the confidence in severe accident code predictions. A benchmarking exercise encompassing the various severe accident codes in use within the HWR community is important not only for providing confidence in the overall performance of the codes but also for the reduction of uncertainties in their predictions.

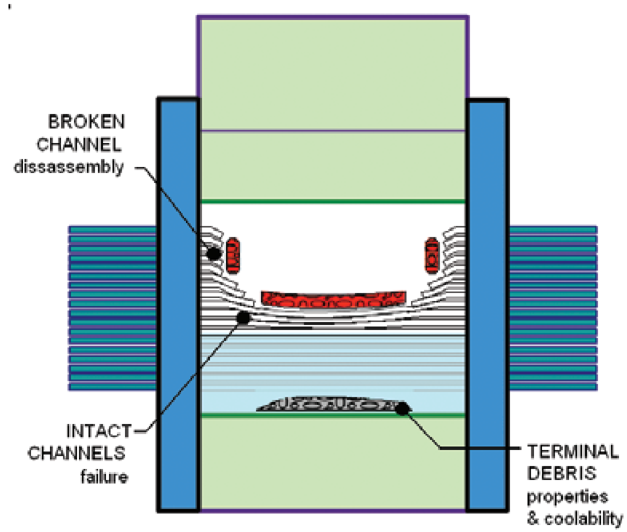


Figure 1: Fuel channel disassembly phenomena (conceptual – not to scale).

The IAEA started a CRP in 2009 on benchmarking severe accident computer codes for HWR applications to improve the safety for currently operating plants and to facilitate more economic and safe designs for future plants. The expected outcomes from this CRP are:

- improved understanding of the importance of various phenomena contributing to event timing and consequences of a severe accident,
- improvement of emergency operating procedures or severe accident management strategies,
- advanced information on computer code capabilities to enable the analysis of advanced HWR designs.

The CRP scope includes:

- collection and evaluation of existing models, correlations, experiments, and computer codes applicable to HWR severe accident analysis
- determination of reference design and severe accident scenario for benchmarking analysis considering operating HWRs and available computer codes in Member States

- establishment of criteria for fuel failure, fuel channel failure, fuel channel disassembly, core collapse, calandria vessel failure and containment failure, and reactor vault failure
- benchmark analysis for Phase 1 (accident initiation to fuel channel dryout), Phase 2 (fuel channel dryout to core collapse), Phase 3 (core collapse to calandria vessel failure), and Phase 4 (calandria vessel failure to containment failure).

3.2 Heat transfer behaviour and thermo-hydraulic code testing for super critical water cooled reactors

There is high interest internationally in both developing and industrialized countries in innovative super-critical water-cooled reactors (SCWRs), primarily because such concepts will achieve high thermal efficiencies (44-45%) and promise improved economic competitiveness utilizing and building on the recent developments for highly efficient super critical fossil power plants.

The higher coolant temperatures proposed for SCWR systems imply fuel cladding temperatures greater than current nuclear reactor operating experience. Because of enhanced heat transfer for supercritical flows and the use of new cladding materials with low corrosion rates, it is necessary to have precise information for establishing both the neutronic and the thermal limits. Consequently, in developing SCWR designs, experimental data for the convective heat transfer from fuel to coolant, covering a range of flow rate, pressure and temperature conditions, are required. Collection, evaluation and assimilation of existing data as well as deployment of new experiments for needed data are necessary to establish accurate techniques for predicting heat transfer in SCWR cores.

Validated thermo-hydraulic codes are required for design and safety analyses of SCWR concepts. Existing codes for water-cooled reactors need to be extended in their application and improved to model phenomena such as pressure drop, critical flow, flow instability behaviour, and transition from super-critical to two-phase conditions.

The IAEA CRP on SCWRs promotes international collaboration among IAEA Member States for the development of SCWRs in the areas of heat transfer behaviour and testing of thermo- hydraulic computer methods. Specific objectives of the CRP are:

- to establish a base of accurate data for heat transfer, pressure drop, blowdown, natural circulation and stability for conditions relevant to supercritical fluids,
- to test analysis methods for SCWR thermo-hydraulic behaviour, and to identify code development needs.

3.3 Natural circulation phenomena, modelling and reliability of passive systems

The use of passive safety systems such as accumulators, condensation and evaporative heat exchangers, and gravity driven safety injection systems eliminate the costs associated with the installation, maintenance and operation of active safety systems that require multiple pumps with independent and redundant electric power supplies. Another motivation for the use of passive safety systems is the potential for enhanced safety through increased safety system reliability. As a result, passive safety systems are being considered for numerous advanced reactor concepts.

The IAEA CRP, entitled "Natural Circulation Phenomena, Modelling and Reliability of Passive Safety Systems that Utilize Natural Circulation", was conducted during 2004-2009. Specific objectives of the CRP were:

- to establish the status of knowledge: passive system initiation & operation; flow stability, 3-D effects and scaling laws
- to investigate phenomena influencing reliability of passive natural circulation systems
- to review experimental databases for the phenomena
- to examine the ability of computer codes to predict natural circulation and related phenomena
- to apply methodologies for examining the reliability of passive systems.

The IAEA training course on natural circulation phenomena and passive safety systems in advanced water cooled reactors is one of the outcomes from this CRP. This course provides participants with a comprehensive instruction on natural circulation phenomena and modeling in nuclear power plants. The lecture mate-

Table 1 Classification of passivity

	Category A	Category B	Category C	Category D
Signal inputs of intelligence	No	No	No	Yes
External power sources or forces	No	No	No	No
Moving mechanical parts	No	No	Yes	Limited
Moving working fluid	No	Yes	Yes	Limited

rial was published as an IAEA TECDOC [10]. This course has been held at the International Center of Theoretical Physics (Trieste, Italy) and other locations worldwide almost annually since 2004.

As shown in Table 1, four categories in different degrees of passivity are defined and used in IAEA [11]. Passive safety systems in Category D are used in many advanced designs and they can be characterized as having active initiation and passive execution. A second publication from this CRP is a document that examines passive safety systems adopted by 20 reference designs including evolutionary and innovative concepts to identify the thermo-hydraulic phenomena involved in each passive safety system [12].

The third publication is a TECDOC that includes the improvement in the understanding of each phenomenon, with sample analyses for some integral tests and NPPs, and sample applications of the methodology to examine the passive system reliability [13].

4. International collaborative standard problems

IAEA ICSPs provide a structured approach to advance the understanding of neutronic, thermo-hydraulic, fuel or materials behaviour in advanced nuclear power plants, as well as the performance of nuclear plant systems. ICSPs can be established to

- provide a comparison of best-estimate computer code calculations to experimental data under controlled conditions;
- evaluate the capability of computer codes to adequately predict the occurrence of important phenomena, and the corresponding behaviour of nuclear systems during operating, upset and accident conditions, which are represented in experiments.

4.1 Computer code validation for HWR LBLOCA with RD-14M test

Most internationally recognized codes used for LWR design and safety analysis have been subjected to systematic validation procedures through a number of international programmes. This IAEA ICSP was the first international initiative to compare the performance of codes against experiments for HWR systems.

The reference experiment was performed in the RD-14M test loop located at the AECL Laboratories in Pinawa, Canada. The RD-14M facility is a pressurized water loop with essential features similar to the primary heat transport loop of a typical CANDU 6. A Large Break Loss- of-Coolant Accident (LBLOCA) test, named B9401, was selected as the reference case. This case includes the limited temperature excursion in the core shortly after the LOCA and the demonstration of the performance of the emergency core cooling system. Six different institutes using four different codes and six different idealizations participated in the activity performing the blind and post-test analyses of the B9401 experiment. All codes are two-fluid six-equation codes, except one that is a three-equation code with the drift-flux capability. The strengths and weakness of the codes were identified and the ways to improve the prediction were studied. The participants benefited greatly from the analysis of this experiment due to the exchange of expertise and information that was not available in the open literature [14].

4.2 Computer code validation for HWR SBLOCA with RD-14M test

Building on the successful completion of the ICSP on HWR LBLOCA, a new IAEA ICSP on a HWR Small Break Loss-of-Coolant Accident (SBLOCA) was started in 2007. The objective of this ICSP is to improve the understanding of important phenomena expected to occur in SBLOCA transients, to evaluate code capabilities to predict these important phenomena, their practicality and efficiency, and to suggest necessary code improvements and/or new experiments to reduce uncertainties. Two RD-14M SBLOCA tests were selected for blind calculations. Eight institutes from six HWR countries are currently participating in this ICSP.

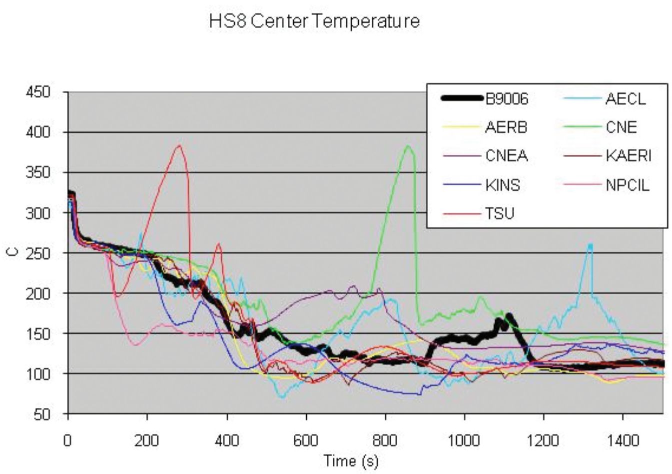


Figure 2: Comparison of fuel element simulator temperature.

4.3 Integral PWR design natural circulation flow stability and thermo-hydraulic coupling of containment and primary system during accidents

IAEA ICSP on an integral Pressurized Water Reactor (PWR) design has been prepared as a follow-up to the CRP on natural circulation phenomena, modelling and reliability of passive systems that use natural circulation.

Natural circulation flow stability and thermo-hydraulic coupling of primary system and containment during accidents are important phenomena to be examined for integral PWR design. The specific objectives of the ICSP are:

- to compare the best-estimate computer code calculations to the experimental data obtained from the integral test facility representing an integral type reactor
- to improve the understanding of thermal-hydraulic phenomena expected to occur in normal operation and transients in an integral reactor
- to evaluate the capability of computer codes to adequately predict the occurrence of important phenomena, and the corresponding behaviour of nuclear systems during operating, upset and accident conditions, which are represented in experiments.

Oregon State University (OSU) in the USA has offered their experimental facility for this ICSP. The OSU MASLWR test facility models the MASLWR conceptual design including reactor pressure vessel cavity and containment structure. The scope of the ICSP includes two types of experiments: 1) single and two phase natural circulation flow stability tests with stepwise reduction of the primary inventory, and 2) loss of feedwater transient with subsequent ADS (Automatic Depressurization System) blowdown and long term cooling by primary-containment coupling. Participating institutes will perform three phases of simulations (double-blind, blind and open) for the experiments with their own computer codes.

5. Data Bases

5.1 ARIS

IAEA Member States, both those just considering their first nuclear power plant and those with an existing nuclear power program, are interested in having ready access to the most up- to-date information about all available nuclear reactor designs as well as important development trends. To meet this need, the IAEA has developed ARIS (the Advanced Reactors Information System), a web-accessible database that provides Members States with comprehensive and balanced information about all advanced reactor designs and concepts. ARIS includes reactors of all sizes and all reactor lines, from evolutionary water cooled reactor designs for near term deployment, to innovative reactor concepts still under development, such gas cooled and fast reactor or small- and medium-sized reactors. ARIS allows users to sort and filter the information based on a variety of relevant criteria, thus making it easy to capture the general trends and to identify the differences between the diverse designs and concepts.

The data stored in ARIS is compiled by the IAEA based on the information provided by the developers of each reactor design/concept, and harmonized to result in an unbiased and easy to use source of information. Although the depth of the reactor descriptions may vary depending on the level of development of the various concepts, ARIS includes reports on nuclear steam supply system, safety concept, plant performance, proliferation resistance, spent fuel and waste management, as well as a complete list of technical data. The information is updated whenever there is any significant change on a specific design. The ARIS is accessible from the IAEA public website at http://aris.iaea.org.

Figure 3: ARIS data base.

5.2 THERPRO

From 1999 to 2005 the IAEA carried out a CRP on establishment of a thermo-physical properties data base of materials for LWR and HWR. The objectives of this CRP were to collect and systematize a thermo-physical properties database for light and heavy water reactor materials under normal operating, transient and accident conditions and to foster the exchange of non-proprietary information on thermo-physical properties of LWR and HWR materials. An internationally available, peer reviewed database of properties at normal and severe accident conditions (THERPRO: http://therpro.hanyang.ac.kr) has been established at Hanyang University (Republic of Korea), and now provides various material properties data and an interactively accessible information resource and communications medium for researchers and engineers. TECDOC-1496 [15] describes the content of THERPRO database. Registering to use freely the THERPRO database is easy by visiting the THERPRO website.

6. Summary and conclusions

HWRs are the second most common type of nuclear reactor installations in the world, second only to LWRs. Therefore, high priority should be given to the development of technology to achieve economic competitiveness with other energy sources and to assure high safety levels for HWRs.

The IAEA mission to foster and facilitate HWR technology development in Member States is successfully carried out through the organization of coordinated research projects, international collaborative standard problems, technical meetings, international collaborative assessments and training courses and workshops.

7. References

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Status of Advanced Light Water Reactor Designs: 2004, IAEA-TECDOC-1391, IAEA, Vienna (2004).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Heavy Water Reactors: Status and Projected Development, TRS-407, IAEA, Vienna (2002).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Status of Small Reactor Designs without On-site Refuelling, IAEA-TECDOC-1536, IAEA, Vienna (2007).

[4] INTERNATIONAL ATOMIC ENERGY AGENCY, Status of innovative small and medium sized reactor designs: 2005: Reactors with conventional refuelling schemes, IAEA-TECDOC-1485, IAEA, Vienna (2006).

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, Advanced Applications of Water Cooled Nuclear Power Plants, IAEA-TECDOC-1584, IAEA, Vienna (2008).

[6] INTERNATIONAL ATOMIC ENERGY AGENCY, Improving Economics and Safety of Water-Cooled Reactors: Proven Means and New Approaches, IAEA-TECDOC-1290, IAEA, Vienna (2002).

[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Inter-comparison of techniques for inspection and diagnostics of heavy water reactor pressure tubes: Flaw detection and characterization, IAEA-TECDOC-1499, IAEA, Vienna (2006).

[8] INTERNATIONAL ATOMIC ENERGY AGENCY, Inter-comparison of techniques for inspection and diagnostics of heavy water reactor pressure tubes: Determination of hydrogen concentration and blister characterization, IAEA-TECDOC-1609, IAEA, Vienna (2009).

[9] INTERNATIONAL ATOMIC ENERGY AGENCY, Good practices in heavy water reactor operation, IAEA-TECDOC-1650, IAEA, Vienna (2010).

[10] INTERNATIONAL ATOMIC ENERGY AGENCY, Natural circulation in water cooled nuclear power plants: phenomena, models, and methodology for system reliability assessments, IAEA-TECDOC-1474, IAEA, Vienna (2005).

[11] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety related terms for advanced nuclear plants, IAEA-TECDOC-626, IAEA, Vienna (1991).

[12] INTERNATIONAL ATOMIC ENERGY AGENCY, Passive safety systems and natural circulation in water cooled nuclear power plants, IAEA-TECDOC-1624, IAEA, Vienna (2009).

[13] INTERNATIONAL ATOMIC ENERGY AGENCY, Natural circulation phenomena and modelling for advanced water cooled reactors, IAEA-TECDOC-XXXX, IAEA, Vienna (2011).

[14] INTERNATIONAL ATOMIC ENERGY AGENCY, Inter-comparison and validation of computer codes for thermal-hydraulic safety analysis of heavy water reactors, IAEA- TECDOC-1395, IAEA, Vienna (2004).

[15] INTERNATIONAL ATOMIC ENERGY AGENCY, Thermo-physical Properties Database of Materials for Light Water Reactors and Heavy Water Reactors, IAEA- TECDOC-1496, IAEA, Vienna (2006).

Correction

In the report on the Waste Management, Decommissioning and Environmental Restoration for Canada's Nuclear Activities, in the September 2011 issue, Vol. 32, No.3, of the *CNS Bulletin* there were errors in the spelling of two names.

The conference chair was **Colin Allan** and the plenary speaker from OECD-NEA was **Hans Riotte.**

Safety Benefits From CANDU Reactor Replacement A Case Study

by R. MOTTRAM[1], J.W.F. MILLARD[2] and P. PURDY[1]

[Ed. Note: The following paper was presented at the "International Conference on Future of Heavy Water Reactors: Towards Sustainability" held on October 3-5, 2011, in Ottawa, Ontario, Canada.]

Abstract

Both total core replacement and core retubing have been used in the CANDU® industry. For future plant refurbishments, based on experience both in new construction and in recent refurbishments, the concept of total core replacement has been revisited. This builds on practices for replacement of other large plant equipment like boilers. The Bruce CANDU reactors, with their local shield tanks built around the Calandria and containment closely located around that Calandria Shield Tank Assembly (CSTA), are believed to be good candidates for core replacement.

A structured process was used to design a replacement CSTA suitable for Bruce A use. The work started with a study of opportunities for safety enhancements in the core. This progressed into design studies and related design assist safety analysis on the reactor. A key element of the work involved consideration of how verified features from later CANDU designs, and from our new reactor design work, could be tailored to fit this replacement core. The replacement reactor core brings in structural improvements in both calandria and end shield, and safety improvements like the natural circulation enhancing moderator cooling layout and further optimized reactivity layouts to improve shutdown system performance.

Bruce Power are currently studying the business implications of this and retube techniques as part of preparation for future refurbishments. The work explained in this paper is in the context of the safety related changes and the work to choose and quantify them.

1. Introduction

Both total core replacement for smaller reactors and core retubing have been used in the CANDU industry. In 2008 Bruce Power (B.P.) commissioned a feasibility study to see if it was technically feasible to replace a Bruce A station core and whether there would be advantages in this alternate approach. The study utilized experience both in new construction and in recent refurbishments.

It built on practices for replacement of other large plant equipment like boilers. The Bruce CANDU reactors, with their local shield tanks built around the Calandria and containment closely located around that Calandria Shield Tank Assembly (CSTA), are believed to be good candidates for core replacement. The paper focuses on the work carried out to demonstrate that quantifiable safety benefits could be obtained with a modified design and with no negative consequences.

2. Project development

An important element of the proposed refurbishment of the Bruce units is keeping them in compliance with modern standards, especially with regard to safety. This process is typically documented and formalized against the requirements laid out in CNSC Regulatory Document (RD) 360 [1]. RD360 is multifacetted and involves carrying out an Integrated Safety Review with 14 elements. The safety review is then collated in two main documents. These are

- The Global Assessment Report (GAR) that seeks to integrate all of the 14 elements and ensure that any interactions between them are considered
- The Integrated Implementation Plan (IIP) that identifies the program for any mitigation or improvement action to be completed

Internal drafts of the Bruce 3&4 Global Assessment Report and Integrated Implementation plan, which assumed fuel channel replacement, were used to understand plant wide issues that would relate to the CSTA replacements study. Given this work was concerned with just the reactor core, a subset of those steps and total scope was then used for the study, rather than an update of the complete plant unit document. It was recognized that replacement of the reactor core allows potential implementation of further safety improvements which would not be feasible to perform using a conventional fuel channel detube/retube approach, so the project added items to the proposed improvements contained in the current draft documents.

This paper highlights the process followed to show that the requirement toward continuing Safety improvements had been addressed if a new CSTA was to be constructed. It primarily focuses on the route towards

1 Bruce Power, Tiverton, Ontario, Canada
2 Atomic Energy of Canada Limited, Mississauga, Ontario, Canada

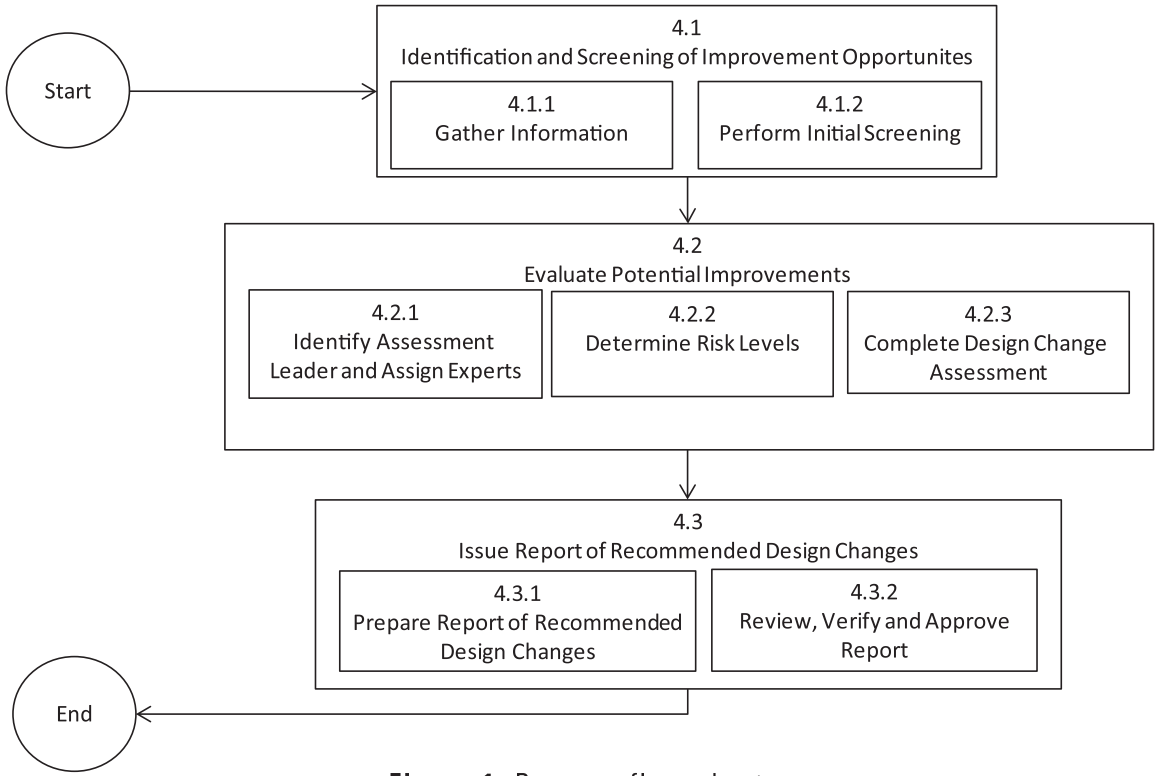


Figure 1: Process flow chart.

acceptable design modifications followed, showing the amount of Analysis work that was required to confirm positive results and to ensure that there were no negative impacts from the proposed changes.

3. Process developed

A Bruce Power engineering department procedure was prepared that defined the steps that would be followed to produce an approved design basis for a modified CSTA.

Figure 1 shows the process Flow Chart for that procedure.

The Key principles that must be met through performance of the process were:

- The plant, with the final list of improvements, must meet the relevant regulations and the current site licence,
- defence in depth is maintained and,
- safety margins are maintained or improved.

As per the process flow chart the assessment started with a safety related screening of opportunities for improvement. Identification of improvement oppo rtunities was done by a rigorous evaluation of the elements which drive the safety performance as analyzed in the safety report. These were centered on areas where a change in core design could improve performance, and also by comparison with the safety performance of other CANDU reactors. The work considered an evaluation of the Bruce A accident scenarios with lowest safety margins as part of a feature-by-feature comparison of the Bruce A reactor core safety features with later CANDU reactors. A diverse panel of experts was used to look both at possible benefit of each potential improvement for Bruce A core, as well as the risk and cost. The expert panel contained a cross section of expertise with many tens of years of experience from Bruce Power, AECL and their contractors.

Concurrent with the safety review, OPEX was reviewed and operational and design improvements were considered. Operations data and design data from newer CANDU reactors was reviewed to assemble a list of potential hardware changes beyond those driven directly by Safety impact. From the OPEX, operations and design information and the review of safety performance, the information was fed into an activity to produce requirements for and then to design the replacement reactor. The most significant areas for improvement identified were SDS1 depth and moderator cooling.

4. Safety analysis plan

Having collated a list of items with perceived safety benefits, and started reactor design work, a Safety Analysis Plan was produced by a group consisting of representatives from Bruce Power Nuclear Safety and Support (NSAS) and BP projects together with AECL® and Candesco.

The safety analysis plan mapped out the safety support requirements into 4 phases. The first series of calculations, design assistance in nature, were aimed at supporting the conceptual and detail design work to allow sizing and layout decisions to be made in the reactor core. The second series of calculations were more of a verification nature covering postulated accident cases and comparing the design assist results with the existing Bruce A core to document the improvements. The principle objective of these phases was to enable NSAS to support the proposition that the changes in the CSTA would not have any negative impact on the Safety Case and thus remove a major risk item affecting a decision to proceed with the replacement approach. Phases 3 and 4 would be completed if a decision was made to go ahead with a replacement approach, and would cover production of a revised Safety Report and any proposed performance changes such as increases in power or changes in life expectation.

5. Modelling safety performance

Modelling the performance of the coupled interaction of the various reactor and process systems around it is vital to both design and safety analysis work. A variety of codes are used, primarily those agreed as Industry Standard Toolset (IST) codes. [2] These verified codes make use of a mixture of theory, reactor data, and data from specialized facilities like the RD14 test loop at AECL Whiteshell and the ZED2 physics facility at AECL Chalk River Laboratories to model the performance of key systems and components in CANDU reactors. These include codes like:

- DRAGON IST which does three dimensional neutron transport calculations.
- WIMS IST A general purpose reactor physics program for core physics calculations. It contains verified lattice models of the reactor core.
- Reactor Fuelling Simulation Program (RFSP) which uses model input s from WIMS or Dragon and is Capable of generating nominal power distributions and simulating reactor operations, including refuelling and burnup steps.
- Canadian Algorithm for Thermalhydraulic Network Analysis (CATHENA) Capable of analyzing two-phase flow and heat transfer in piping networks. This was used for moderator and end shield system performance analysis
- TUF a two phase flow thermohydraulics code with integrated neutron transport which is hard coded to reflect the configuration for a given reactor and concentrates on the heat transport system response.
- MODTURC, a three dimensional computation fluid mechanics code based on porous media approximations written for moderator thermohydraulics calculations

These codes are used individually and in concert using verified models and input data sets from Bruce Power with some new models and modified data sets created by AECL.

6. Safety calculations

In the safety support calculations the codes modelled the physics responses, the thermohydraulic responses, and coupled responses since the two responses directly affect each other. AECL and NSAS specialists cooperated to pick the most suitable toolsets to both allow comparison to current Bruce safety analysis but also provide the extra data that comes from some of the available design focused codes. For the new reactor core existing fuel channel modeling and input data sets were obtained from verified Bruce Power TUF models. Using WIMS some simple core optimization calculations were done before using DRAGON to come up with incremental changes to the modified core from the existing verified Bruce Power Models. This then allowed the reference Bruce Power RFSP model to be updated and run with TUF to get the updated response of the new core. Fuelling runs were performed for start and 8250 EFPD to get the bounding conditions for break analysis.

For the moderator performance work a new model was produced in MODTURC which was compared to the CANDU 9 quarter scale test facility measurements [3] and had sensitivity numbers run on variations of inlet and outlet nozzle positions. This model used as input the physical geometry modeled in CAD and RFSP runs to get both the heat lost from the fuel channels and also the nuclear heating into the moderator fluid from the reaction in the core.

Simple network calculations and CATHENA were used to model the overall system flows around the moderator circuit and match the new calandria layout and piping to the existing system equipment to rematch the system flows to those currently existing. A CATHENA model of the end shield was also produced both to allow with a simple network calculation the system flows to be matched up as well as to be used for larger deterministic reactor level calculations of response of the new design.

Having built up these core models to allow steady state numbers to be worked out for key values like shutdown reactivity margin, fuel bundle and channel powers, and key temperatures like moderator steady state, they were then used for analyzing postulated accident transients. Bounding flux tilt and creep values were chosen appropriately for individual cases. This included an In core Loss Of Coolant Accident (LOCA) run where a break of a new uncrept pressure tube and subsequent calandria tube break was run through a coupled TUF and RFSP to look at the system response as the event progressed. This was compared to the existing unit performance to show both the significantly improved shutdown margin as the control system reacted to the event but also to compare responses as the event progressed. A large out of core accident was also simulated using conditions from later in life

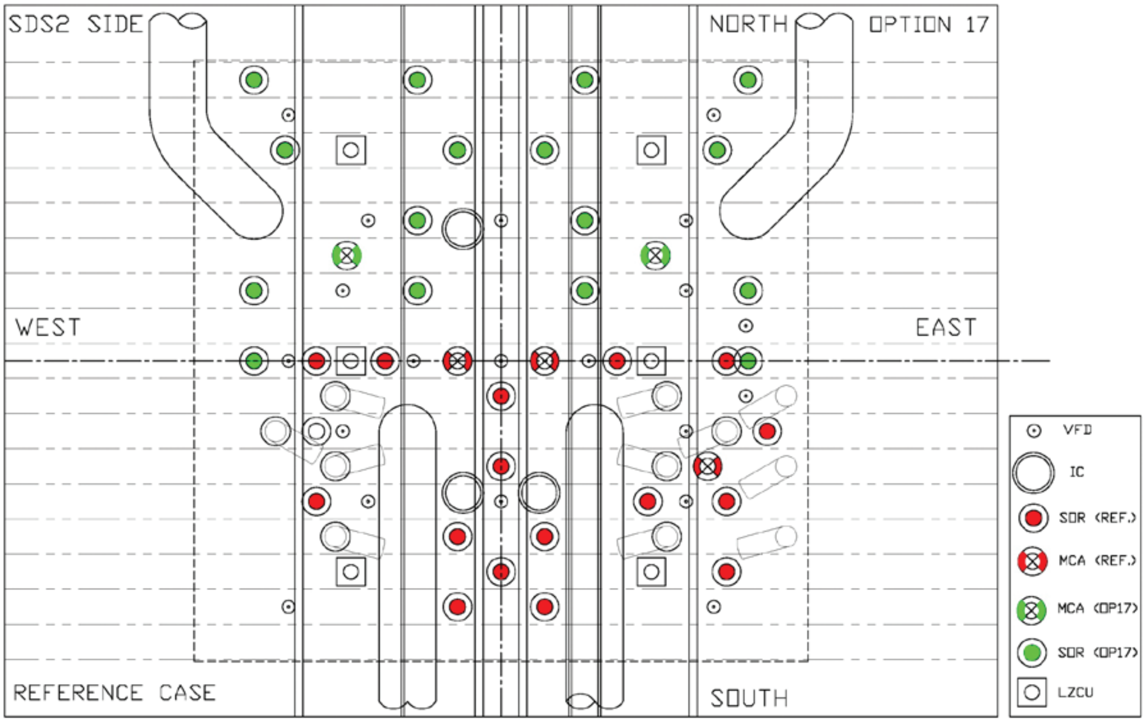


Figure 2: Comparison of reactivity deck equipment locations.

to see the progression of that accident and make sure the dynamic response of shutdown system 1 had not significantly changed. The new deck layout had moved the rods outward in the core giving more of them slightly further to travel for the important gate 1 way point. For this case the increased worth of the new shut off rod layout did not directly impact the event but simply gave a larger margin at the end. The impact of the small overall gate 1 change was also quantified and shown to be acceptable.

The analysis results were compared to the analysis of record for the current Bruce A to investigate the effect of the design changes. Overall it was shown the changes do give significant safety improvements on a number of postulated events with no negative effect on the plant safety as a result. As the design work is moved forward further detailed safety support calculations are planned on accident transients to support the formal stress analysis for final registration and build towards an updated safety report.

7. Some safety outcomes

7.1 SDS1 depth

The evaluation identified that SDS1 depth was limiting for some accident scenarios and so should be considered for improvement. This led into a conceptual evaluation of the shutoff rods and their layout to see if improvements could be achieved. In that evaluation initial simplified physics runs showed that, with several new layouts, a significant increase in worth could be gained via a movement of the absorber rod positions in the core, made possible by the removal of the booster assemblies.

The more detailed safety support calculations included a comparison of many shutoff and control absorber positions. With these calculations the reactivity device layout was optimized to keep the zone control positions and the same detector signals to the operators already seen for units 1 & 2 while improving the step back symmetry and increasing shut off rod depth.

Figure 2 shows a comparison of the current and proposed configuration of SORs and MCAs. The top shows the proposed modified design while the bottom half shows the current Bruce A design.

7.2 Moderator cooling

Moderator cooling was originally designed for Bruce A to cool booster fuel first, and then circulate through the calandria vessel second. The booster fuel itself had been removed from use in Bruce A cores several decades ago but the flows remained as per the original design. Removal of the assemblies allowed the moderator cooling design to be redesigned using the latest verified concepts. This brought in a design that reinforced the normal nuclear heating currents to move coolant through the core thus bringing in a more efficient cooling, which in turn greatly reduced the temperature range through the core, and with that made the performance in postulated accidents more predictable and controllable. In past work [4] [5] the original moderator temperatures were modeled based on temperature probes inserted into the Bruce 3 core and then used to verify a software model

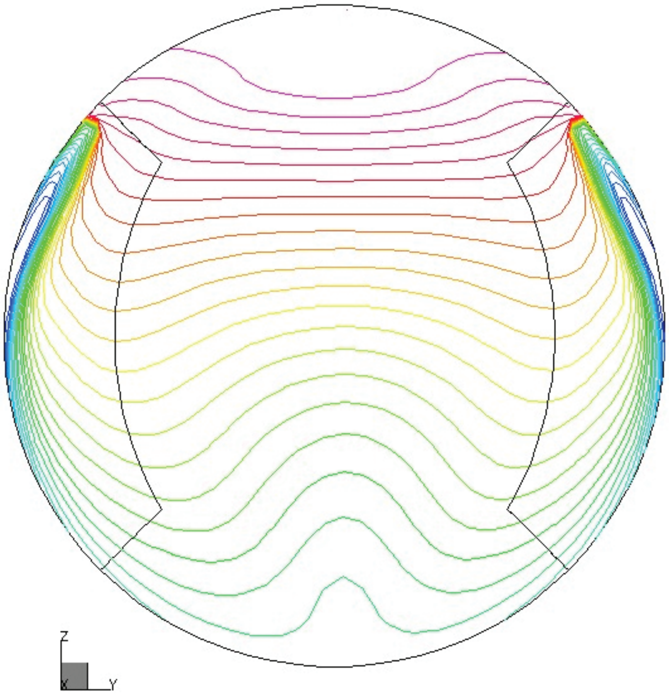


Figure 3: Improved moderator temperature distribution.

to fully analyze that original momentum based cooling scheme. The new buoyancy based scheme was proved [6] through a combination of a quarter scale model and associated with that a verified computer model. Figure 3 shows the predicted temperature distribution in the replacement calandria vessel as a result of the move to buoyancy based cooling.

The response of the moderator cooling circuit was modeled showing both several degrees of extra subcooling margin and with the smaller range of temperature in the moderator more even reactivity response and the ability related to this to obtain small improvements in reactivity coefficients that affect postulated accident progression.

8. Design

In addition to these changes the review process identified others for more detailed investigation, minor LISS nozzle clearances, and improved guide tube venting to mitigate hydrogen. The list of safety related changes was combined for this new CSTA with a larger list of many non safety related OPEX driven improvements to the CSTA. A further item from that first safety list on shield tank venting was adopted after detail design work. The additional items were primarily concerned with detail design improvements like changing the weld details on the nozzles on the calandria shell to improve alignment of thimbles containing reactivity devices, and a move to a simpler end shield structure with two sheets and a simpler cooling layout. A number of these detail design changes bring in operational, and to a lesser degree safety benefits. For example, improved access for operation and maintenance to the safety related items on the reactivity mechanism deck, and with the revised end shield structure a potential for thermosyphoning should coolant flow be interrupted. The safety assessment and rational behind the selections were recorded in a document which was reviewed with CNSC in 2010 gaining general acceptance of the work.

Examples of some of the other changes are Fuel Channel design end fitting bearings, Fuel Channel restraints, LISS nozzle profile, RCU locator details, and Moderator level measurement.

Following documentation of the requirements the more detailed design work included both structural analysis and a more in depth safety support calculations. Using structural analysis the updated detail design of the calandria, end shield and shield tank was updated to be fully compliant with modern codes and standards. This provided the basis for a classification and preliminary registration submission for this replacement CSTA. A number of challenges were encountered during this work as the original construction and registration of the current vessels was completed prior to the introduction of the "modern approach to coding. The first of two main issues was associated with a currently designed moderator system being Class 1 equivalent and the new code not allowing bellows in a Class 1 circuit. Bellows are obviously required in the SOR guide tubes to allow for thermal movements. The second issue was a proposal to treat the replacement vessel as a component in its own right rather than its being the collection points of a number of discrete systems. Resolution of these issues remain on-going at the time of writing this paper.

Given the assembly of the CSTA was modified to suit the new vertical installation a revised access path into the shield tank during installation was needed. This was fashioned to be capped off after commissioning using a rupture disc to prevent pressurization of the shield tank and preserve its integrity in severe accidents.

The design and its supporting analysis was recorded in a set of arrangement drawings, and related design and design support documents. These included the specification and analysis required for provisional registration, documents to allow a detailed pricing of the replacement CSTA to be performed, and a classification document with related pressure boundary drawing for regulator discussion on how the replacement CSTA would be constructed to current codes and incorporated into the existing process systems.

9. Summary

A structured process was used to design a replacement CSTA suitable for Bruce A use [7]. The work started with a study of opportunities for safety enhancements in the core. This progressed into design studies and related design assist safety analysis on the reactor. A key element of the work involved consideration of how verified features from later CANDU reactor designs, and from new reactor design work, could be tailored to fit this replacement core. The replacement reactor core brings in structural improvements in both calandria and end shield, and safety improvements like the natural circulation enhancing moderator cooling layout and further optimized reactivity layouts to improve shutdown system performance. Bruce Power is currently studying the business implications of this replacement approach against retube techniques as part of preparation for future refurbishments. The work explained in this paper is in the context of the safety related changes and the work to choose and quantify them.

The paper demonstrates the level of detail considered to ensure that risks around any decision to proceed with a CSTA replacement program would be minimized as they relate to reactor Safety issues.

10. Acknowledgements

This work was carried out in AECL and Bruce Power. The Authors would like thank their colleagues who demonstrated exceptional cooperation between NSAS and AECL specialties, and performed the detailed analysis discussed here. A large team of several tens of staff was involved in production of the many documents and drawings and the verification reviews performed as part of it.

11. References

[1] Canadian Nuclear Safety Commission Regulatory Document (RD) 360, Life Extension of Nuclear Power Plants, 2008.

[2] Safety Analysis Technology: Evolution, Revolution and the Drive to Re-Establish Margins, John C Luxat, Seminar presentation, Canadian Nuclear Society, Sheridan Park Branch, 2000.

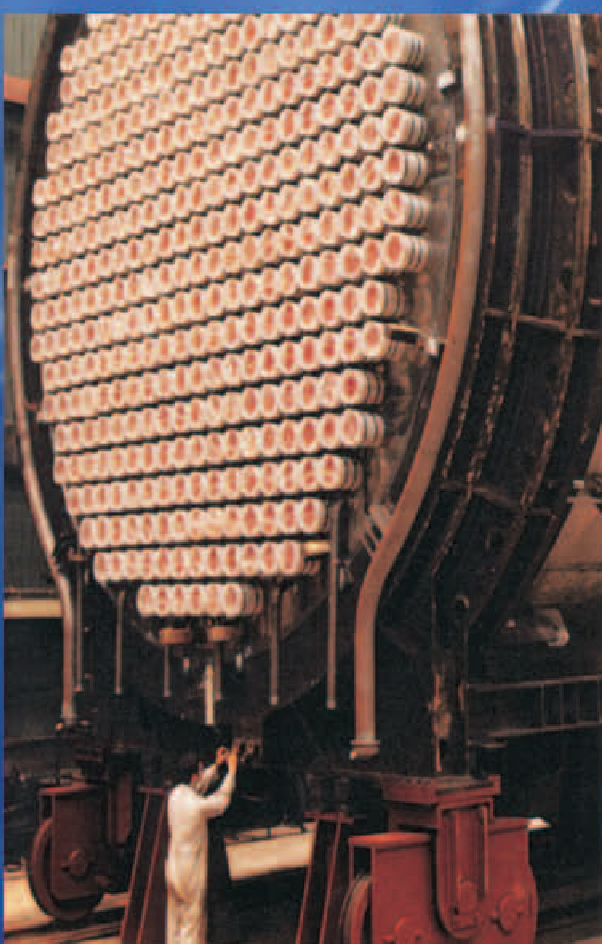
[3] ACR moderator circulation, D. Wren presentation to NRC, 2002.

[4] Measuring Moderator Temperature in a CANDU Reactor, G Austman et al, 1985.

[5] In Core moderator measurement within CANDU Reactors, N Sion, 1982.

[6] Thermalhydraulic Design Methods and Computer Codes, Xu Jijun et al, 1999.

[7] Calandria and Shield Tank Replacement option for Bruce 3&4, R. Mottram et al, 2011.



From Microwatts to Megawatts: Early Development of Natural Uranium/Heavy-Water Reactors

by JAMES E. ARSENAULT, P.Eng.

Introduction

The unique design approach of the Canada Deuterium Uranium (CANDU) family to the management of nuclear energy, using natural uranium and heavy water to produce power, came about for many reasons but the beginnings can be traced back to experiments carried out in Europe on the eve of the Second World War. At the time it was known that energy was available from the fission of uranium but no one knew how to extract it in a practical way. It was also realized that if the energy could be controlled, it could be used to generate power and conversely, if uncontrolled, for military purposes. This article traces the early lineage of Canadian reactors and how natural uranium/heavy-water reactor power grew from the order of microwatts to megawatts in a mere seven years.

Progress in atomic science

The phenomenon of radioactivity in uranium was discovered by Henri Becquerel in 1896 and radium, an even more energetic source, was isolated by Marie Curie in 1898. However, it was only with the theoretical explanation of radioactivity by Rutherford at McGill University in 1902 that nuclear science began in earnest. Thereafter the world witnessed the artificial disintegration of elements (Rutherford in 1919), splitting of the atom (Cockcroft and Walton in 1932), the neutron (Chadwick in 1932), heavy water (Urey in 1932), artificial radioactivity (M. and F. Joliot-Curie in 1934), and moderated neutrons (Fermi in 1934). Near the end of 1938 Hahn and Strassmann discovered the fission of uranium and in early 1939 it was shown, by Frisch and Meitner, to be accompanied by a great deal of energy. Complementing the discoveries of the experimentalists was quantum mechanics, which developed to provide an overarching theory to explain the reactions being observed.

Discoveries were published in the leading physics journals and conferences were held regularly so that the laboratories were always aware of what lines of inquiry were underway. There was considerable competition between the leading research laboratories. With the discovery of fission and the release of energy it was realized that it might be feasible to use this energy for both peaceful and military purposes. It was quickly understood by many leading scientists that this could only be achieved by continuous fission in uranium, that is, a chain reaction was needed.

In 1939, as the Second World War approached, atomic research was centred mostly in Europe, especially in the cities of Paris, Berlin and Cambridge, and to a lesser extent in a few institutions in North America (Columbia University, University of Chicago, University of California at Berkley). Canada had a small program at the National Research Council (NRC) in Ottawa which was mainly concerned with assisting the uranium mining industry and some research was carried out in universities, most notably McGill, Dalhousie, Queen's, and Toronto [Sargent, 1979].

Of all the great laboratories, the Collège de France in Paris, the home of many Nobel Laureates in physics and chemistry, was most interested in the liberation of atomic energy from uranium for the generation of power although the researchers there were certainly aware of the explosive possibilities.

Paris 1939: chain reactions

The Collège de France grew up on a rather ad hoc basis as an alternative to the Sorbonne, to teach science in the making and to draw on the best researchers of the day. This certainly applied to Marie Curie, who received two Nobel Prizes (Physics in 1903 and Chemistry in 1911) for her pioneering scientific work. Eventually she became head of the Collège's Uranium Institute where many people were trained in nuclear science and went on to make their own discoveries. These included Frederic and Irene Joliet-Curie, the codiscoverers of artificial radioactivity for which they were awarded a Nobel Prize (Chemistry in 1936). Irene was the daughter of Marie and she married Frederic in 1926, after which the couple took the name Joliet-Curie [Weart, 1979].

Eventually Frederic Joliet-Curie was able to set up his own laboratory at the Collège and formed a team that set out to discover how to exploit the energy released by atomic fission. In this endeavour he was joined by Hans von Halban and Lew Kowarski, both of whom had trained at the Uranium Institute. Their first experiment was performed in February 1939 in a tank 0.5-m across, filled with a water/uranium compound

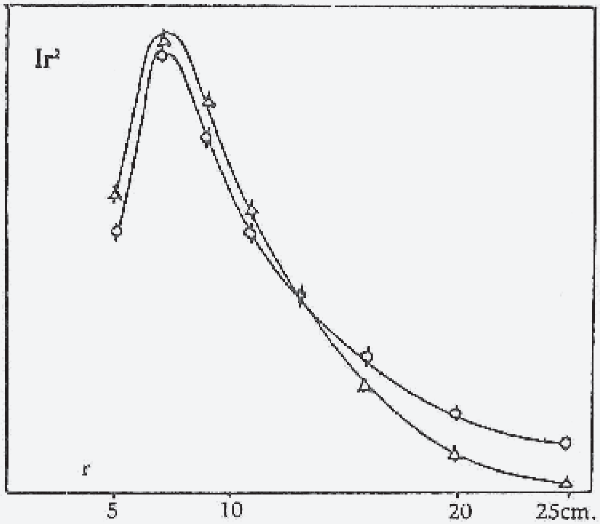


Figure 1: Evidence of a Fission Reaction.

mix with a radium/beryllium source of neutrons at the centre. The activity was measured using a dysprosium detector in conjunction with a Geiger counter, first with the mix and then with water only. They plotted the density distribution curves using the I squared R method pioneered by Fermi, which plots activity versus distance from the centre. Clear evidence of a chain reaction was obtained based on the fact that the two curves behaved in accordance with crude theory. This result was published in March 1939 and is shown in Figure 1 [von Halban et al., 1939, p. 470].

The team then did an experiment which was intended to establish the number of neutrons that are given off in each uranium fission by aiming neutrons at a 2-cm thickness of water and measuring the proportion that got through. The result obtained was 3.5 +/- 0.7 (the modern value is 2.5 [Wiles, 2009]), and was published in May 1939 [von Halban et al., 1939, p. 680]. Now the world knew with certainty that a chain reaction was possible but the problem remained of how to make the reaction self-sustaining. Also in May, Joliet-Curie decided to file patents in France covering a) a basic nuclear reactor, b) the means for controlling it, and c) a nuclear bomb. Later these were to become a constant source of distrust between the U.K. and the U.S. governments when they tried to work jointly on atomic matters.

In June, in preparation for larger experiments, operations were moved to Joliet-Curie's larger laboratory at Ivray, southeast of Paris. He was confident that the experiments were safe because early calculations indicated that about 45 T (later calculations came out at 5 T) of uranium would be required to reach criticality, i.e., a self-sustaining reaction.

In July, experiments began using using a 30-cm copper sphere filled with a uranium oxide/water mixture which was placed in a 3-m tank filled with water, to measure activity in the sphere as well as in the surrounding water. These were followed by experiments with 50-cm and 90-cm copper spheres. Additional experiments were carried out using uranium/carbon piles, similar to those Fermi was carrying out contemporaneously at Columbia. Eventually the team realized that they would need purer materials to minimize neutron absorption, to obtain a sustained reaction in a scaled-up reactor. After reviewing the results they decided that it would be more practical to use uranium with a better moderator and they settled on heavy water, which has a moderating ratio about 25 times that of carbon [Wiles, 2009].

The storm clouds of war hovering over Europe finally broke on 1 September 1939 when Germany invaded Poland; then obtaining rare materials like heavy water became a problem. The only source of heavy water was a power company in Norway, Norsk Hydro, that manufactured it in small quantities for research purposes in laboratories around the world. The story of how the team obtained a supply of heavy water is a dramatic one of great intrigue involving a high-stakes game of cat and mouse [Dahl, 1999]. When the heavy water (185.5 kg in 26 cans) arrived in February 1940, the team was preparing to repeat the sphere experiments with a motorized rotating sphere designed by Joliet-Curie, to keep the uranium mix uniform by preventing it from settling at the bottom of the sphere. However, the experiment was never carried out because France was being overrun by the German Army and in June 1940 Paris was about to fall. Joliet-Curie decided to remain in France but sent von Halban, Kowarski, their families, laboratory papers, and the heavy water south to catch a ship to the U.K. As a result another great adventure ensued but the heavy water eventually arrived safely in London in late June 1940 [Weart, 1979].

It is interesting to note that at about this time George Laurence at the NRC began to investigate the possibility of building a carbon/uranium pile. In the next two years he succeeded in constructing a pile but concluded that materials with fewer impurities were necessary to obtain a chain reaction. It is likely that Laurence was inspired by the work done at the Collège.

Cambridge 1940: a heavy-water reactor

The Cavendish Laboratory of Cambridge University was the final home of Rutherford and many other Nobel Laureates in nuclear science and had trained students from around the world including Canada. The possibilities for the use of atomic energy for commercial and military use were well known in the U.K. and universities, including Cambridge, were involved in research to that end when von Halban and Kowarski arrived. At this time atomic research was coordinated by the M.A.U.D. Committee, which was a cover name to disguise the nature of their work.

Halban ('von' usually was omitted from his name from this time on) and Kowarski were under orders

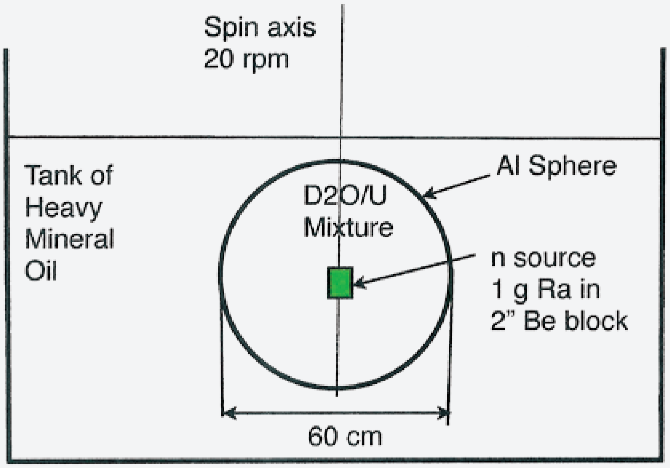


Figure 2: First Subcritical Heavy-water Reactor.

from the French government to "carry on in England the researches undertaken at the Collège de France" [Weart, 1979]. Initially they wanted to go to North America and, therefore, wanted the British to send them to a small laboratory in Canada. However, the M.A.U.D. Committee decided to assign Halban and Kowarski space at the Cavendish Laboratory in Cambridge [Gowing, 1964]. Joliet-Curie's planned experiment with heavy water went ahead using the apparatus shown in Figure 2, using 120 kg of heavy water and about 1 kg of uranium.

In late November they were able to begin measuring density-distribution curves and by December the results were compiled into a report which contained the following statement (it was underlined):

"*The results discussed below give the experimental proof that such a divergent chain, maintained by slow neutrons, can be produced in a mixture of uranium oxide and heavy water.*" [Halban and Kowarski, 1940]

This seems to be the first experiment indicating that a working uranium/heavy-water reactor could become a reality. The report also discussed the theory that such a reactor could produce the highly fissile element 94 (X)239, that was named plutonium in 1942. Thus the M.A.U.D. Committee endorsed the heavy-water line of research as it could lead to a weapon, which was the main interest of the Committee.

The M.A.U.D. Committee produced a large report in June 1941, part of which discussed the work of Halban and Kowarski.

"*Their results showed a definite indication of a divergent chain process; for each initial neutron 1.06 +/-0.02 were produced in one set of experiments, 1.05 +/-0.015 in another set.*" [Gowing, 1964]

The report goes on to state that the system was small, using only 180 kg of heavy water and that the critical size of the system would require 3 to 6 T of heavy water. Further:

"*We are informed, however, that steps are being taken in the U.S. to produce heavy water on a large scale, and since Drs Halban and Kowarski have done all that they can with the supplies which they brought to this country, we think that they should be allowed to continue their work in the U.S.*" [Gowing, 1964]

In the fall, the whole atomic effort in the U.K. was reorganized and given the code name Tube Alloys in order to distract from its true purpose. Wallace Akers, the Research Director of Imperial Chemical Industries was appointed to lead the effort and Halban was placed in charge of slow neutron research. Then in early 1942, Akers led a mission to the U.S. to establish firm cooperation and Halban tried to attach his research to the Metallurgical Laboratory University of Chicago, where work on heavy water became centered. This was refused on the basis of security, as most of Halban's associates working in the U.K. were refugees from German-held territory. Halban then proposed, with U.S. approval, that his team be transferred to Canada to form the nucleus of a larger Anglo-Canadian group [Goldschmidt, 1989].

In early September the British sought a definite answer to the proposal from C.J. Mackenzie, Acting Director of the NRC, and he favoured the arrangement in principle. In late September Halban was in Ottawa and events moved quickly from then on. The organizational structure was agreed, Montreal was selected for the location of the laboratory (in the partly finished Medical Wing of the University of Montreal), personnel and equipment arrived from the U.K. (including the heavy water), and the recruitment of Canadian personnel began. U.S. cooperation was assured and the whole affair was approved by C.D. Howe, Minister of Munitions and Supply [Mackenzie, 1942–46].

In mid-September all atomic work in the U.S. was placed under control of the U.S. Army and the Manhattan Project began to expand rapidly [Groves, 1983]. As a result the Army imposed a military security blanket on atomic matters, much to the detriment of the Anglo-Canadian group.

Believing that full cooperation of the U.S. was in place, Mackenzie ordered a full list of needed raw materials for Halban's laboratory in mid-December. The list included: 3 T of uranium oxide specially processed for purity, 4 T of uranium metal in the form of rods, 0.5 T of uranyl nitrate, 60 T of graphite, and 6 T of heavy water [Eggleston, 1966]. From the list it is obvious that Halban was planning a comprehensive research program capable of producing a full-scale operating reactor. He might have succeeded except that Fermi at the University of Chicago brought the world's first self-sustaining reactor of the carbon pile type into operation in early December and, thereafter, cooperation was next to nil. The U.S. had lost interest in the Montreal effort because they had devised a clear path to a weapon through the transformation of ura-

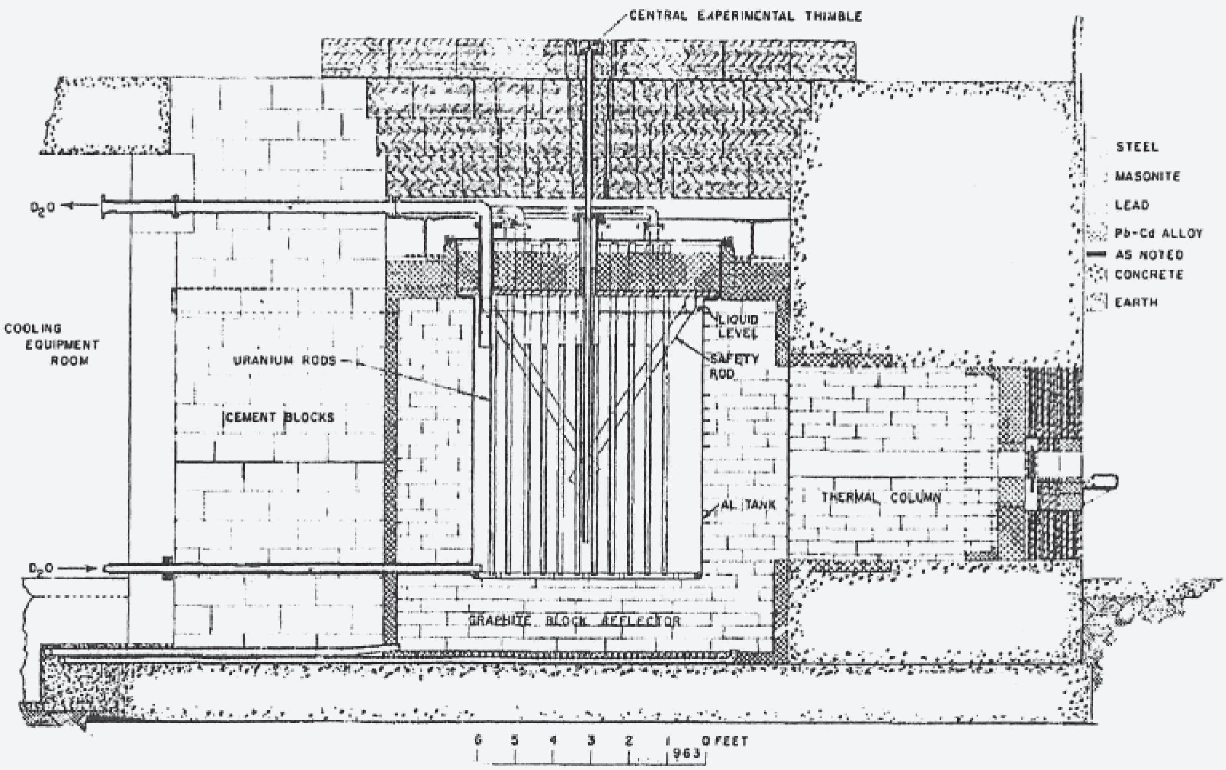


Figure 3: Heavy-water Reactor CP-3.

nium metal into fissile plutonium, in quantity, via the use of large, graphite-based, water-cooled piles (which were still to be designed).

Montreal 1943: Pinnochio arrives

In the beginning, the Montreal Laboratory (ML) operated under Halban, with department heads for Theory, Chemistry, and Engineering. Halban was to take direction from a management committee consisting of Halban, department heads, and George Laurence of the NRC, who was active in the recruitment of Canadian personnel. This committee met rarely and the direction of the Laboratory drifted under Halban, who had little experience in what today would be called Project Management. Policy was set by C.D. Howe, the British High Commissioner Malcolm McDonald, and C.J. Mackenzie [Eggleston, 1966].

The final shipment of equipment from the U.K. arrived in April and it included the aluminum sphere, code named Pinnochio, used by Halban and Kowarski in their heavy-water experiments at the Cavendish Lab. With the ML denied most of the materials necessary for experimentation, it nevertheless managed to accomplish a great deal with what it was able to obtain, including a remeasurement of the original experiment by Halban and Kowarski at Cambridge. The results obtained were in general agreement. Other major work was concerned with various homogeneous and heterogeneous reactor design concepts and the engineering problem of heat removal from reactors [Laurence, 1980; Williams, 2000].

Chicago 1944: CP-3 goes critical

While work at the ML grew more frustrating due to lack of cooperation by the U.S., the scientists in Fermi's group at the University of Chicago began to design the large water-cooled graphite production piles to produce plutonium, which would be built at Hanford, Washington. This decision was taken after Walter Urey, the discoverer of heavy water, had argued that heavy water offered a more efficient route to the production of plutonium. However, heavy water was in short supply and Fermi had shown that the graphite pile offered a more direct route. This activity was regarded as a production task and was handed over to the DuPont Company's engineering group. This upset the Chicago group greatly, as they were required to review DuPont's plant drawings. To keep peace they were also assigned the task of designing and building a heavy-water, natural uranium pilot reactor, known as CP-3 (Chicago Pile), at the nearby Argonne Forest Laboratory site [Dahl, 1999]. The pilot project was led by Walter Zinn (Canadian-born), who had been in charge of building Fermi's pile at Chicago. Construction began in September 1943 and criticality was achieved in May 1944. A diagram of the CP-3 reactor is shown in Figure 3 [Zinn, 1956].

CP-3 is described briefly as follows:

"*The reactor consists of an aluminum tank of diameter 6 ft into which are suspended a maximum of 136 natural uranium metal rods, 6 ft long and of diameter 1.1 in. ... the uranium rods are spaced in a square lat-*

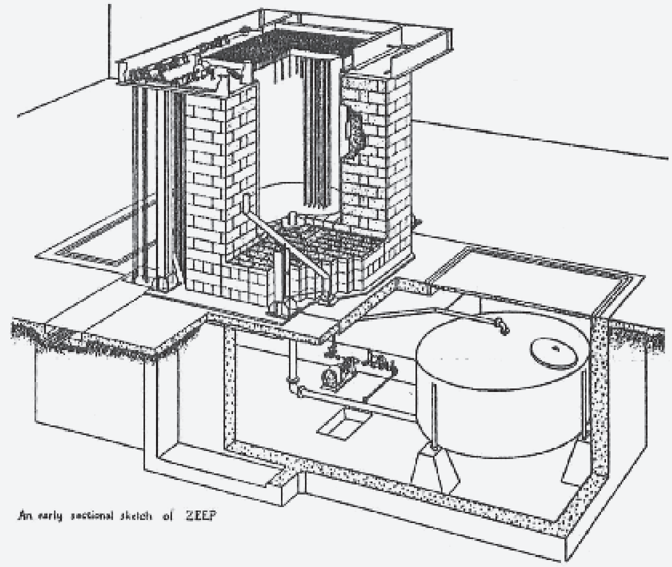


Figure 4: ZEEP Reactor.

tice of T5 3/8-in. pitch. The aluminum tank wall is 3/16 of an inch thick and is surrounded by a graphite reflector of 2-ft thickness. A water-cooled gamma ray shield made of Pb-Cd alloy and a 7 ft 8-in. thick concrete layer completes the shielding. The top of the reactor is closed by a shield made up of laminated blocks of wood and steel. … The aluminum jacket of thickness 0.035 in. is drawn down onto the uranium rod by a die to give a close fit for better heat transfer.

Heat released from the uranium rods is transferred by natural convection to the bulk moderator in the tank. Suction of hot heavy water from the top of the reactor and return of cooler water through a pipe at the bottom of the aluminum tank is the method of cooling. … The heavy water pumped from the reactor tank is forced through a heat exchanger where it is cooled with light water." [Zinn, 1956]

The maximum power output of the reactor was 300 kW and it used 6.5 T (Dahl, 1999) of heavy water and 3.2 T of natural uranium. Note: the value of 3.2 T is derived from comparison with the rods supplied by the U.S. for the Zero Energy Experimental Pile (ZEEP) reactor [Green, 2005].

Chalk River 1945: ZEEP goes critical

Progress at the ML continued in a state of limbo and Canada threatened to cancel its contribution. Then in August 1943 the Quebec Conference took place, at which the U.S. and the U.K. governments finally resolved the cooperative impasse with 'Articles of Agreement Concerning Collaboration between Authorities of the U.S.A. and the U.K. in the matter of Tube Alloys'. To guide the activity, a Combined Policy Committee (CPC) was set up in Washington, and Canada was represented on the Committee by C.D. Howe [Gowing, 1964].

At this point James Chadwick became the scientific liaison officer on behalf of the U.K. and U.K. scientists were integrated into the U.S. research activities in the following months. This left the ML status to be resolved and little real interest was shown by the U.S. but Chadwick saw the value of their work and he was determined to assign the ML a useful wartime project, acceptable to all concerned. He set out to convince the U.S. that a heavy-water reactor could be built before the war would end and that it would produce plutonium more efficiently because of the inherently high neutron flux present.

At the CPC in February 1944, Chadwick proposed that a 10-MW heavy-water pilot plant would be designed and built in Canada. The U.S. demurred but in mid-April the reactor project was approved by the CPC. Later the reactor became known as the National Research Experimental (NRX) reactor. One of the associated conditions was that Halban was to be replaced as Laboratory Director. John Cockroft was selected and he arrived on the scene in the latter part of April.

Things moved quickly with liaison visits being held with the scientific group at the University of Chicago for exchange of information on reactor design and plutonium extraction techniques. The Chalk River site for the new laboratory was selected in July and construction began in the same month. Chalk River had the desired characteristics of good drainage, ample cooling water, remoteness from large centres, rail access and a good power supply that could be supplemented.

Eventually materials in the form of uranium rods and heavy water were supplied to the project by the U.S. [U.S. Army, 1947]. In the meantime Cockcroft decided that a small demonstration reactor should be constructed to gain operating experience and make measurements in order to get the rod lattice spacing optimized for NRX. Thus the ZEEP project was given approval in August to proceed with the design, and approval for construction was given in October [Green and Okazaki, 2005]. Kowarski, who had stayed behind at Cambridge, was recruited by Cockcroft to act as project manager and George Klein of the NRC acted as chief designer [Borgeois-Doyle, 2004]. The reactor went critical on 5 September 1945, 16 months from conception and after 11 months in construction. At this stage it is estimated that the reactor contained 3.9 T of natural uranium [Green, 2005] and 5.0 T of heavy water [Dahl, 1999]. An outline drawing of the reactor is shown in Figure 4 [Bourgeois-Doyle, 2004].

ZEEP is described briefly as follows:

"*Fuel Rods: Natural uranium slugs 6 in. long, 1.28 in. diameter, stacked in 9 ft. aluminum tubes and suspended from movable beams … Average number of rods is 120 … Fuel Core: Cylindrical aluminum tank open at top and convex at bottom, 8 1/2 ft. high and 6 3/4 ft. in diameter. Maximum capacity about 10 tons heavy water… Reflector: Three ft. graphite on sides; 2*

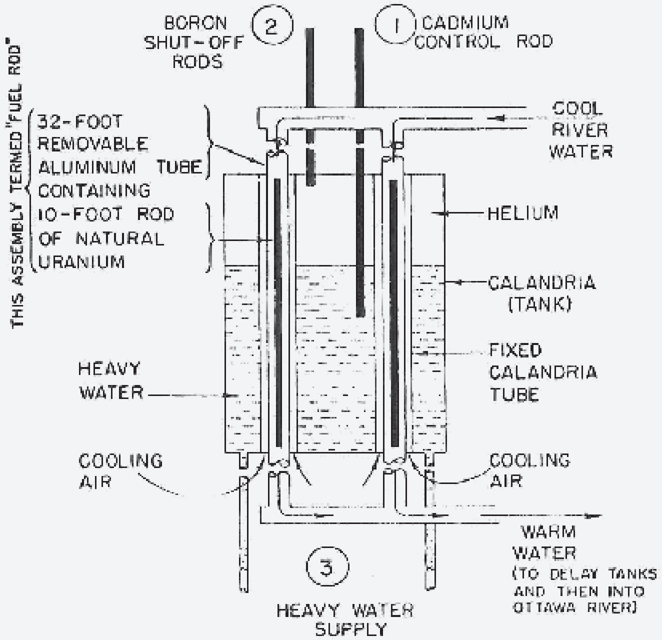


Figure 5: NRX Reactor.

1/2 ft. on bottom. Shielding: Tanks 3 ft. thick containing ordinary water around reactor. Concrete lid can be installed on top. Possible to operate continuously at 10 watts ... for an 8-hour exposure ... up to 250 watts ... Overall Size: About 25 ft. square and 15 ft. high. Coolant: None. Temperature: Room temperature. Control: Cadmium-coated stainless steel plates jacketed in aluminum, operating in the vertical gap between core and reflector... Two sets of four shut-off rods ... consisting of stainless steel coated with cadmium and jacketed in aluminum." [Kennedy, 1956]

Chalk River 1947: NRX goes critical

The project expanded quickly and at the end of August 1944 there were 198 personnel organized in the following categories: Nuclear Physics, Technical Physics, Chemistry, Engineering, Theoretical Physics, Administration and Extra Mural Workers (Ottawa, Hamilton, Toronto). NRX was designed by the scientists of the ML and was constructed by Defence Industries Limited (DIL) [Cockroft, 1944]. To accomplish the detailed design, the scientific knowledge developed by the ML was captured and passed on to the engineers employed by DIL in a series of 43 lectures presented between August and September 1944 [NRC Montreal Laboratory, 1945]. Cockcroft left in September 1946 to take up new duties in the U.K. and was replaced by W.B. Lewis. The construction of NRX encountered numerous delays and quality problems but finally, on 22 July 1947, NRX went critical. An outline drawing is shown in Figure 5 [Kennedy, 1956].

NRX is described briefly as follows:

"*Fuel Rods: Each rod assembly contains a natural uranium rod 10 1/4 ft. long and 1.36 in. in diameter, sheathed in aluminum 0.08 in. thick and surrounded by a cooling water annulus 0.07 in. thick. Weight of each of the 176 uranium rods is 120 pounds; total weight of uranium in reactor up to about 10 1/2 tons. Fuel Core: Right cylindrical aluminum tank (called a "calandria") 8 3/4 ft. in diameter and 10 1/2 ft. high, with fixed aluminum tubes running from end to end (much like a firetube boiler). Tubes are 2.25 in. inside diameter; space between calandria tubes and fuel rod assemblies forms cooling air annulus. ... Calandria contains up to 3,300 gallons (18 tons) of heavy water. Reflector: 9 in. of graphite, then 2 1/2 in. gap for thorium rods, followed by a further 2 ft. of graphite. The total weight of graphite is 58 tons. Shielding: Immediately above the calandria is a water-cooled aluminum shield, followed by two water-cooled steel shields each weighing 15 tons, then four concrete shields each weighing from 17 to 19 tons. Immediately below the calandria is a water-cooled, 2 in. thick "sandwich", followed by four water-cooled steel shields. Around the calandria are two 6 in. thick cast iron thermal shields separated by a cooling air channel, followed by 7 to 8 ft. of concrete. Overall Size: Thirty-four ft. in diameter and rises 30 ft. above main floor. Coolant: Up to 3,500 Imperial gallons per minute of river water, mostly to the fuel rods. Air flow of 70,000 pounds per hour for shields and thorium rods. Temperature: Coolant water temperature rise is 40C (104F). Heavy water maintained at a fixed temperature less than 49C (120F) by circulating through ordinary water heat exchanger at 250 gallons per minute. Reflector is not allowed to exceed 149C (300F). Control: Six shut-off rods of boron carbide powder in steel tubes; one control rod of cadmium slugs in steel tube. All operate in vacant fuel-rod positions.*" [Kennedy, 1956]

Aftermath

The Collège de France experiments were critical in establishing approaches to produce energy from nuclear chain reactions, pointing to the use of heavy water in reactors. However, the planned experiments with uranium/heavy-water were interrupted in June 1940 as Paris was invaded and Halban and Kowarski relocated to the Cavendish Laboratory. There they showed the first evidence of a subcritical chain reaction in a homogeneous uranium/heavy-water mixture.

The present location of Pinnochio, the aluminum sphere used by Halban and Kowarski at Cambridge in the latter half of 1940 and shipped to Montreal in early 1943, remains unknown. Perhaps someday it may be found at the Chalk River Laboratory. As for the 180-kg supply of heavy water, all of which was requested to be returned to France, apparently only about 15 kg was shipped [Smith, 1989].

CP-3 went critical in May 1944 and with one change of fuel (in 1950) it was kept in continuous operation for ten years, at which time it was taken out of service. It was in excellent operating condition and could have continued to serve usefully for many more years. The heavy water and uranium was removed from CP-3 and the shell was filled with concrete and buried at the Argonne National Laboratory site. An historical marker has been placed at the site.

ZEEP achieved criticality in September 1945, three days after the formal end of W.W.II. It was operated intermittently and was involved in many wide-ranging experiments until July 1970, when it was shut down for the last time after nearly 25 years of service. In 1947, the heavy water was removed and it was transferred to NRX in its run up to criticality. In 2005 most of the important parts of ZEEP were dismantled and then reassembled at the Canadian Museum of Science and Technology in Ottawa, where it remains on display.

NRX went critical in July 1947. Although originally designed as a 10-MW reactor to produce plutonium, it reached 20-MW one year later but only 17 kg of plutonium was extracted from the chemical processing facility. For many years NRX had the highest neutron flux of any reactor in the world. In December 1952 during some experiments a combination of failures and errors led to a runaway condition and the reactor was severely damaged. There were no fatalities or serious injuries and the accident served to strengthen the approaches to safe reactor design in Canada [Stead, 2007]. Fourteen months later NRX had been rebuilt and reached a power level of 40 MW. NRX served as a source of neutrons for physics experiments, as a major engineering test reactor, and as a producer of isotopes for over 40 years until it was shut down in 1989. NRX was instrumental in the shared 1994 Nobel Prize in Physics awarded to Bertram N. Brockhouse. He used NRX in the 1950s and advanced the detection and analysis techniques used in the field of neutron scattering for condensed matter research. After 45 years of operation, NRX was shut down permanently in April 1993 and still is undergoing decommissioning.

In 1952 the Atomic Energy Project of the NRC was transferred to a newly created crown corporation, Atomic Energy of Canada Limited. Following on the heels of NRX came a stream of new reactors leading in a direct line to the highly successful CANDU family of power reactors and other reactors designed for research.

Conclusion

The historic evolution of Canadian natural uranium/heavy-water power reactors is summarized in Table 1. The power output, beginning at a negligible magnitude (microwatts) in experiments, progressed to 10 MW in a mere seven years. It is no exaggeration to say that ZEEP and NRX were the foundation of the Canadian nuclear industry because they provided reference designs and the needed experience for the evolution of all Canadian reactors that followed.

"These reactors provided the basis for the development of fundamental nuclear power technology." [Ball, 1987]

Progress can be measured by comparing the 10-MW NRX to the CANDU power reactors of today, which operate with capacities in the 540-MW to 934-MW range, with designs for 1000-MW ongoing [CNS, 2011].

Acknowledgments

Thanks are due to Lyn Arsenault for her editing skills in getting this article ready for publication. I am grateful to the staff of the Churchill Archives Centre, Cambridge, U.K., for providing a copy of the original report on the experiments of Halban and Kowarski performed in the U.K. The suggestions and encouragement of Fred Boyd are greatly appreciated.

References

Ball, N.R. "Mind, Heart, and Vision", Professional Engineering in Canada 1887 to 1987. National Museum of Science and Technology, National Museums of Canada, Ottawa. 1987.

Table 1 Summary of Early Heavy-water Reactors

REACTOR	LOCATION	D2O	U	FLUX (a)	POWER	CRITICAL	DATE	REMARKS
Various	Collège de France	185.5 kg	--	--	--	No	4002--	D2O arr. Paris
Al. Sphere	Cambridge	120 kg	1 kg	--	--	No	401219	Fission with D2O
	Montreal	120 kg	1 kg	--	--	No	430404	Sphere arr. Montreal
CP-3	Chicago	6.5 T	3.2 T	10exp12	300 kW	Yes	440926	CP-3 startup
ZEEP	Chalk River	5.0 T	3.9 T	--	1 W	Yes	450905	ZEEP startup
NRX	Chalk River	18.0 T	10.5 T	10exp13	10 MW	Yes	470722	NRX startup

Note:
a. Neutrons/sq. cm./sec.

Bourgeois-Doyle, R.I. George J. Klein: the Great Inventor. NRC Research Press, Biography Series No. 2, National Research Council. Ottawa. 2004.

CNS. 2011 Nuclear Canada Handbook. Canadian Nuclear Society, Toronto. 2011.

Cockcroft, J.D. NRX Project, Progress Report for August, 1944 and September, 1944. National Research Council Archives, Ottawa. 1944.

Dahl, P.F. Heavy Water and the Wartime Race for Nuclear Energy. Institute of Physics Publishing, London. 1999.

Eggleston, W. Canada's Nuclear Story. Harrap Research Publications, London. 1966.

Goldschmidt, B. "How it All Began in Canada – the Role of the French Scientists." In: Malcolm Harvey, ed. Special Symposium: 50 Years of Nuclear Fission in Review. Sponsored by CNS/CNA, Ottawa. June 5 1989. (http://www.cns-snc.ca/history/fiftyyears/goldschmidt.html; accessed 031128)

Gowing, M. Britain and Atomic Energy 1939-1945. Macmillan & Co. Limited, London. 1964.

Green, R.E. E-mail sent to author. Subject: ZEEP Article. November 2005.

Green, R.E. and A. Okazaki. "ZEEP: Canada's First Nuclear Reactor." Canadian Nuclear Society Bulletin, Vol. 26, No. 3, p.18-23. September 2005.

Groves, L.M. Now It Can be Told. Da Capo Press Inc., New York, N.Y. 1983.

Halban, H. and L. Kowarski. Report I, Interaction of Slow Neutrons with Heavy Water and with U3O8-D2O Mixtures: Experimental Results and Conclusions. Churchill Archives Centre, Cambridge, UK. 19 December 1940.

Kennedy, C. C. Atomic Energy in Canada. Atomic Energy of Canada Limited, Chalk River, Ontario. 1956.

Laurence, G.C. Early Years of Nuclear Energy Research in Canada. Atomic Energy of Canada Limited, Chalk River, Ontario. May 1980.

Mackenzie, C.J. Extracts from Dr. C.J. Mackenzie's Personal Diary of Items Relating to Atomic Energy 1942–1946. RG77, Vol. 283, Library and Archives Canada, Ottawa. 1942–46.

NRC Montreal Laboratory. Manual of Notes on Lectures Given in Montreal Training Course. 2 August-2 October 1945. National Research Council, Montreal. Public records Office, Kew, U.K., AB2/870. 1945.

Sargent, B.W. "Nuclear Physics in Canada in the 1930s." Invited Paper delivered at McGill University. In: History and Philosophy of Science Conference, Otto Hahn and the Rise of Nuclear Physics, 20-21 September, McGill University, Montreal. 1979.

Smith, P. "On the Trail of Drum T-7." In: Malcolm Harvey, ed. Special Symposium: 50 Years of Nuclear Fission in Review. Sponsored by CNS/CNA, Ottawa. June 5 1989. (http://www.cns-snc.ca/history/heavywater/heavywater.html; accessed 031201)

Stead, R.C. Nuclear Power in Canada and Beyond. General Store Publishing House, Renfrew, Ontario. 2007.

U.S. Army. Manhattan District History. Book I General, Volume 4 Auxiliary Activities, Chapter 9 Assistance on the Canadian Pile Project. U.S. Army Corps of Engineers, Washington. 1947.

von Halban, H., F. Joliet, and L. Kowarski. "Liberation of Neutrons in the Nuclear Fission of Uranium." Nature, Vol. 143, p. 470. 1939 (http://Nature.com, accessed 110328).

von Halban, H., F. Joliet, and L. Kowarski. "Number of Neutrons Liberated in the Nuclear Fission of Uranium." Nature, Vol. 143, p. 680. 1939. (http://Nature.com, accessed 110328).

Weart, S. R. Scientists in Power. Harvard University Press, Cambridge, Mass. 1979.

Wiles, D.R. Radioactivity – What It Is and What It Does. Presses Internationales Polytechnique, Montreal. 2009.

Williams, M.M.R., Guest Editor. "Special Issue: Nuclear Reactor Theory in Canada 1943-1946." Progress in Nuclear Energy, Vol. 36, No. 3. 2000.

Zinn, W.H. "Design and description of ANL Reactors (CP-3, CP-3' and CP-5)." Proc. of Int. Conf. on Peaceful Uses of Atomic Energy, Geneva, August 1955, Vol. 2, No. P/861. United Nations, New York. 1956.

Ontario's CANDUs Can Be More Flexible Than Natural Gas-Fired Generation and Hydro Generation

By DON JONES

There is a widely held belief that commercial nuclear-electric plants are only capable of baseload operation when in fact they can be more flexible than a natural gas-fired generating station. This belief has led the Ontario government to restrict nuclear generation to 50 percent of total demand, in its Long-Term Energy Plan, to avoid more surplus baseload generation (SBG). It may also have provided some of the rationale for the expansion of wind/gas generation. In France nuclear meets nearly 80 percent of the electricity demand so the output of nuclear units has to be changed throughout the day to match the load on the grid, load-following. In Ontario the nuclear units operate baseload but units at Bruce B can be held at reduced output overnight when demand on the grid is low, load-cycling.

The Independent Electricity System Operator (IESO) has stated that in general coal-fired units can be dispatched down to 20 percent of full output, and combined cycle gas turbine (CCGT) units down to 70 percent even though they can operate at lower power outputs. Generating units are dispatched by the IESO, that is, sent instructions to raise or lower electrical output, at five minute intervals day and night. If units are operating below their dispatchable power range they will not be able to respond to the dispatch instruction in the time allowed. This means that a hot coal-fired unit is more flexible than a CCGT unit in meeting a variable demand on the grid. Hydro is technically very flexible but suffers from water management regulatory restrictions. New nuclear build in Ontario will be highly manoeuvrable with a dispatchable power range wider than gas or coal and could even have dispatching preference over hydro. See Appendix which describes the operation of the Ontario grid.

In order to be available to help restore the grid after a grid blackout or get back on line after a loss of load all CANDUs (except Bruce A) are capable of quickly reducing reactor power to 60 percent of full power, holding at reduced power, and then returning more slowly to full power using their adjuster rods. The unit electrical output would be held to around 6 percent full power, just enough to supply the plant's auxiliary services load, with the reactor held at around 60% full power and steam bypassed around the turbine to the condenser. Pickering A and B do not have steam bypass to the condenser but bypass steam to atmosphere. The reactors using bypass to condenser can remain at 60 percent full power indefinitely until the grid or load are re-established. In this so called "poison prevent" mode the already hot turbine can then be quickly brought up to 60 percent power to feed the grid causing the bypass valves to close and the slower return to 100 percent power output can then begin. During the 2003 August blackout in Ontario and the north-eastern U.S. some units at Bruce B and Darlington were put in this mode. For various reasons, Bruce A and Pickering A and B units are shutdown after a grid blackout.

All the Ontario CANDUs were designed for baseload operation. Darlington and Bruce B also included the capability for some load-cycling using reactor power changes, without using turbine steam bypass. They were not designed for load-following. In the past some domestic units and off-shore units did accumulate considerable good experience with load-cycling, with some deep power reductions, but not on a continuous daily basis. For example back in the 1980s several of the Bruce B units experienced nine months of load-cycling including deep (down to 60 percent full power, or lower) and shallow reactor power reductions. Analytical studies based on results of in-reactor testing at the Chalk River Laboratories showed that the reactor fuel could withstand daily and weekly load-cycling. Since then, for various reasons, the Bruce and Darlington units have been restricted to base-load operation and are not allowed to vary reactor power for load following or for load cycling although Bruce B is allowed to reduce unit electrical output by bypassing steam that would otherwise go through the turbine. Slow reactor power changes can be made as part of normal operation. Reactor power reductions to around 60 percent of full power combined with steam bypass, poison prevent mode, is still allowed at Bruce B and Darlington for unanticipated events such as a loss of load or grid blackout. For the way that Ontario›s nuclear units interact with the grid see Reference 1.

Since the steam bypass system in the present nuclear units was not designed for the frequent use necessary to alleviate SBG this system should be made more robust as part of the upcoming refurbishment of Bruce and Darlington. Such a system could then provide a degree of load following as well as load cycling, automatic generation control (AGC- see Appendix) and a dispatchable power range better than a CCGT, depending on the design of the steam bypass system. Steam bypass system design and its advantages for units undergoing refurbishment is described in Reference 2. If all the present Ontario units were refurbished to have the same, or better, steam bypass capability as Bruce B, and if many new manoeuvrable units were built, this would go a long way to reducing Ontario›s dependence on precarious gas-fired generation that is subject to future gas price escalation and availability concerns - see Reference 3.

Bruce B units have frequently dropped around 300 MW overnight, using steam bypass, to alleviate periods of SBG. Reactor power is kept constant at full power, around 822 MW. The power down, and later power up, takes up to two hours using a steam bypass system that was not originally designed for this kind of use. This means each unit can provide 300 MW of dispatchable power with electrical output held at 63 percent of full power. On occasion units have dropped over 440 MW to operate at 46 percent of full electrical output. On one early 2011 November weekend, according to an IESO Generator Output and Capability Report, one of the units even reduced reactor power to 385 MW and with steam bypass brought the electrical output down to 208 MW, which is around 25 percent of full power. Under these circumstances this is better than the 70 percent dispatchable limit of the CCGTs. However, for operational reasons to reduce the risk of a unit forced outage, Bruce Power presently prefers to make one big power move, say 300 MW, rather than a series of smaller, say 80 MW, power reductions during any SBG period, which restricts dispatchability somewhat in comparison with CCGTs. SBG is exacerbated by self-scheduling wind generation and since the existing wind generation projects have priority access to the grid it means that nuclear has to be powered down or even shutdown to accommodate wind if hydro and gas generation have been already reduced to must-run power levels. There will be around 8,000 nameplate MW of wind on the grid by 2018, in the belief that it will reduce the greenhouse gas emissions from the gas-fired generation that is replacing coal. Significant reductions are unlikely - see Reference 4. Although it can be done, dispatching clean low cost nuclear, and hydro, to integrate wind makes no technical, environmental or economic sense.

For new CANDU build, whether ACR-1000 or EC6, up to 100 percent steam bypass combined with a reactor power that can be varied if necessary, anywhere between 100 percent and 60 percent full power, would be used to vary unit electrical output down to zero if required, at high up and down load ramping rates. This will provide dispatchable load-following, load-cycling, and AGC capability, with a dispatchable power range much greater than that of CCGTs and coal. Overnight load-cycling would be done by varying reactor power with little if any steam bypass. Although the energy in the bypassed steam is being wasted, at least at present, CANDU fuel costs are very low. Even so, operating the plant regularly at less than full power, whether by reactor power changes or by steam bypass, will reduce the capacity factor and increase the unit cost of electricity generated.

The loading rate of a CCGT unit is set by temperature transients in the thick walled components of the heat recovery steam generator and the rest of the steam side, typically for today's plants up to 5 percent full power per minute. The loading rate of a CANDU unit using steam bypass would be set by turbine metal temperatures, typically up to 10 percent full power per minute with relatively low temperature nuclear steam. This is also better than the maximum 5 percent per minute load ramping rate that the EPR and AP1000 can achieve, and this not over all of their fuel cycle. The hydro stations are extremely flexible and can load at high ramp rates when available. However there can be restrictions on the operation of stored water hydro units due to water management regulations, environmental concerns, and from public safety concerns around the dams because of sudden variations in water levels. All this could reduce the flexibility of some of the hydro generation to respond to dispatches at high ramp rates, so in some circumstances dispatching nuclear units using steam bypass could be a much better option for the grid operator.

France provides a precedent for load-following and load-cycling in Ontario. France has been producing nearly 80 percent of its electricity from its nuclear fleet for many years with the balance coming from hydro and fossil fuels in about equal amounts. France has 58 pressurized light water reactor units on line so the national grid controller can select units that have been recently refueled and have high reserve reactivity so have the flexibility to provide dispatchable load-following, load-cycling, and AGC. Power is varied by so called "grey" control rods and boron use is minimized. Steam bypass is not used for these operations. When units are around 65 percent through their 18 to 24 month fuel cycle they play a diminishing part in load-following and when 90 percent through their fuel cycle they are restricted to baseload operation. CANDU flexibility is not affected by fuel burn-up limitations since it is refueled on-line.

Nuclear is not a one trick pony.

Appendix - How the Ontario power grid works

As of mid 2011 the Ontario grid consisted of 11,446 MW of nuclear with 1,500 MW more refurbished generation to come on line in 2012, 4,484 MW of coal-fired generation, 9,549 MW of gas and oilfired generation mostly combined cycle gas turbine (CCGT) but includes the rarely used 2,140 MW oil/gas-fired Lennox thermal units, 7,947 MW of hydro-electric base, intermediate and peak generation, and 1,334 nameplate MW of wind generation. The grid consists of many generating stations located throughout the province feeding consumers through a network of high voltage transmission lines, transformers, switchgear, and low voltage distribution lines to major consumers including local utilities. Electricity cannot be stored in large amounts so generation and demand has to be kept in balance at all times. If demand exceeds supply all the generators on the grid slow down and the normal grid frequency of 60 Hertz (reversals per second of alternating current) will drop. All electric motors working off the grid would similarly slow down. If supply exceeds demand the frequency will increase. It is the job of the Independent Electricity System Operator (IESO) to ensure that these frequency swings keep within very tight tolerances. It does this by dispatching hydro, coal and CCGT (hardly any simple cycle gas generation) at five minute intervals, not necessarily the same generator, to move power up or down. In the morning the power moves would generally be in an upward direction and in the evening in a downward direction but there can also be small reversals in the general trend. This is called load-following (load-cycling refers to powering down units overnight when demand is low). This brings the grid into a rough balance. In order to bring the frequency into its narrow operating band around 60 Hertz the IESO automatically controls the output of a very small number of selected generators that have the capability to continuously and rapidly vary their output over a seconds to minutes time scale. These are some hydro units at Niagara Falls and, in the past, some coal-fired units. This is called Automatic Generation Control (AGC).

The second to minutes supply/demand variations on the grid, including the erratic fluctuations of wind, are smoothed out by the rotational kinetic energy of the many generators on the grid, by the hydro and fossil turbine-generators on the grid changing their output by normal speed governor action over a limited range (called primary frequency control), and by AGC (called secondary frequency control, normally automatic but can also be done manually). Primary control limits the frequency deviation caused by changes in supply and demand, and secondary control restores the frequency to normal by removing the frequency deviation, or offset, by changing the setpoint of the speed governor of the generating unit(s) on AGC. Nuclear units presently do not take part in frequency control. The current AGC regulation service requirement from the IESO is for at least plus or minus 100 megawatts at a ramp rate of 50 megawatts per minute but this may be changed to allow other generators to supply this service. The designated unit(s) that is on AGC service is kept in its desired operating range by dispatching hydro, coal and combined cycle gas generation at five minute intervals. This dispatching allows for the normal daily demand changes (load-following), including the intermittency of wind. Since valuable hydro is fully committed, gas or coal generation is used to cater for wind intermittency. As well as frequency, voltage levels at points on the grid also have to be maintained but that will not be discussed here.

Reference 1, "IESO - less dispatching of nuclear if you please", Don Jones, http://windconcernsontario.files.wordpress.com/2010/11/ieso-less-dispatching-of-nuclear-if-you-please1.pdf

Reference 2, "Ontario Electrical Grid and Project Requirements for Nuclear Plants", 2011 March 8 report from the Ontario Society of Professional Engineers to Ontario's Minister of Energy, http://www.ospe.on.ca/resource/resmgr/doc_advocacy/2011_sub_8mar_nuclear.pdf

Reference 3, «An alternative Long-Term Energy Plan for Ontario - Greenhouse gas-free electricity by 2045», Don Jones, http://coldaircurrents.blogspot.com/2011/05/alternative-long-term-energy-plan-for.html

Reference 4, "IESO - will Ontario's wind turbine power plants reduce greenhouse gas emissions?", Don Jones, http://windconcernsontario.wordpress.com/2010/08/23/ieso-will-ontarios-wind-turbine-power-plants-reduce-greenhouse-gas-emissions/

Embalse CANDU station in Argentina. Photo courtesy of Candu Energy Inc.

GENERAL news

(Selected by Fred Boyd from open sources)

Bruce Nears Start Up of 1 and 2

On November 30, 2011, Bruce Power operators loaded the last of 5,760 fuel bundles in the Unit 1 reactor, completing the task in a week less than it took to do the same job in Unit 2 a few months ago. The operation in both units was done manually to allow inspection of every bundle as it was inserted into a fuel channel.

Attention will now be given to Unit 2 which is scheduled to start up first. Subject to regulatory approval, that could occur before the end of 2011. Bruce Power expects to synchronize Unit 2 to the grid in the first quarter of 2012 with commercial operation to begin in the second quarter. Start-up of Unit 1 is planned to follow, with synchronization in the second quarter of 2012 and commercial operation in the third quarter.

When all eight units are operating, Bruce Power will have the capacity to supply 6,300 megawatts to the Ontario grid.

The refurbishment of Units 1 and 2 began in 2007 and has involved replacement of the steam generators, all calandria and pressure tubes and upgrades of many ancillary systems. The units originally began operation in 1977 but were laid up in 1995 and 1997. It is expected that they will now be able to operate for at least another 25 years.

Aerial view of the Bruce A NGS.

CNSC Renews Licence of Chalk River

On October 27, 2011the Canadian Nuclear Safety Commission (CNSC) announced its decision to renew the Operating Licence for the Chalk River Laboratories of Atomic Energy of Canada Limited (AECL) for a period of five years. The licence will be valid from November 1, 2011 until October 31, 2016. This includes the NRU reactor.

The Commission, in making its decision, considered information presented at public hearings held on June 8, 2011 in Ottawa, Ontario and on October 4, 2011 in Chalk River, Ontario. During the public hearing, the Commission received and considered submissions from AECL and 14 intervenors, and recommendations from CNSC staff.

With this decision, the Commission incorporates the authorization of activities related to Dedicated Isotope Facility into the renewed operating licence for the CRL site. The Commission requests that AECL prepare yearly reports on compliance monitoring and operational performance. In addition, with respect to operation of NRU, the Commission expects to receive AECL's report on progress made regarding the reactor vessel inspection by the end of February 2012.

An aerial view of part of the Chalk River Laboratories.

Extensive Fuel Melting at Fukushima

A new analysis of the accident at Fukushima Daiichi indicates more extensive fuel melting probably occurred at unit 1 than previously thought.

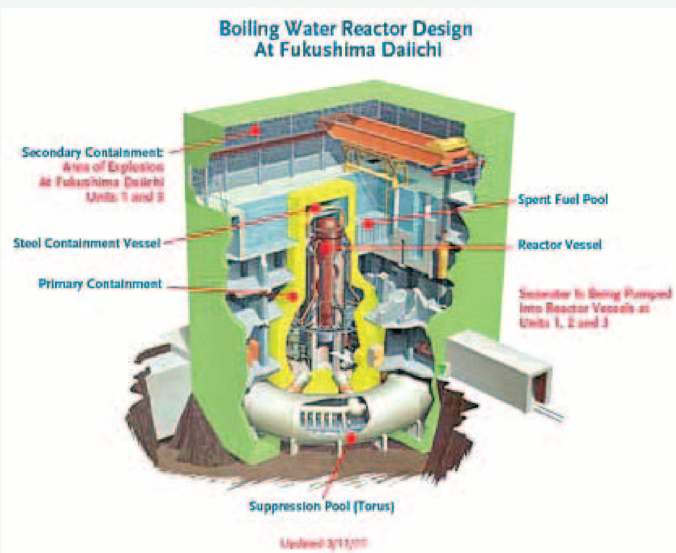
The bulk of unit 1's nuclear fuel went through the bottom of the reactor vessel as well as through about 70 centimetres of the drywell concrete below, according to the analysis released November 30, 2011 by the owner, Tokyo Electric Power Company (TEPCO). However, the corium did not breach the steel containment vessel which is 1.9 metres further down within the concrete, or the boundary of secondary containment some 7.6 metres further still.

Of the 10.2 metres of solid concrete that makes up the floor of the reactor building, the corium is thought to have melted and mixed with the first 70 centimetres only. The natural spreading and expansion of the corium, plus the addition of compounds of concrete, would have reduced the intensity of the heat produced until it reached equilibrium.

The latest analysis was done to supersede one from May due to the emergence of some information that contradicted the early predictions. Because this analysis takes into account some of this data, TEPCO expect this model to be more accurate, although the company cautioned that its scenarios remain uncertain.

Unit 1 was the oldest of the three Fukushima Dei-ichi reactors operating at full power before the earthquake of 11 March, and was hit hardest by the loss of power following the tsunami and the flooding of diesel generators.

For units 2 and 3 the analysis gave similar results to a simulation released in May, actually suggesting that the better of two scenarios presented then is more likely. Nevertheless, the cores of units 2 and 3 are thought to have overheated badly, with a large portion having melted or softened enough to slump to the bottom of the reactor vessel. A relatively small amount is thought to have passed through holes in the pressure vessel and fall to the drywell floor.
(from World Nuclear News)



Bruce Power Pulls Out of Alberta

On December 12, 3011, Bruce Power announced that it had decided not to advance the option for a new nuclear plant in Alberta that has been under consideration by the company since 2007.

When Units 1 and 2 at the Bruce site in Ontario return to service in 2012, Bruce Power, Canada's only private nuclear power generating station, will operate the largest nuclear facility in the world, its eight units producing a quarter of Ontario's electricity and half of the nuclear power in Ontario.

Since late-2007, when Bruce Power acquired Energy Alberta, the company has become known in Alberta and Peace Country, developing and evaluating the possibility of building a new nuclear facility to power Alberta's growing economy.

The Alberta government opened the door to considering the nuclear option, under some conditions, following a public consultation process throughout the province. After extensive analysis and environmental studies, Bruce Power also identified an ideal site.

"There is no question, the option for a new nuclear facility in Peace Country and in Alberta is a strong one and will be an important consideration moving forward," Duncan Hawthorne, Bruce Power president, said. "Over the last several years, we've had strong support from a number of elected officials and citizens in the community and that support continued to grow as the facts about nuclear power became known both in this community and throughout Alberta."

CNSC Licenses Port Granby Waste Project

On November 30, 2011the Canadian Nuclear Safety Commission (CNSC) announced its decision to issue a Waste Nuclear Substance Licence to Atomic Energy of Canada Limited (AECL) for the Port Granby Long-Term Low-Level Radioactive Waste Management Project for a period of 10 years.

This project will receive the historic waste that has been retrieved from around Port Hope . Most of that originated from the early operation of Eldorado Mining and Refining dating back to the 1930s. The site of a waste repository has been studied and discussed for over a decade.

The licence will be valid from the effective date of the land transfer of the Port Granby Waste Management Facility property as set out in the "Agreement of Purchase and Sale" between "Her Majesty the Queen In Right of Canada" and "Cameco Corporation" and "Canada Eldor Inc." and will remain in effect until December 31, 2021 unless otherwise suspended, amended, revoked or replaced. If the land transfer is not concluded within one year from the date this licence is issued, the licence shall terminate.

The Commission, in making its decision, considered information presented for a public hearing held on September 27, 2011 in the Municipality of Clarington, Ontario. During the public hearing, the Commission received and considered the submissions from AECL and 22 intervenors and the recommendations CNSC staff.

GE-Hitachi Proposes Fast Reactor For UK

GE-Hitachi have proposed building two 311 MWe units of their PRISM fast reactor at Schofield, UK. in response to a call from the UK government for submissions on what to do with its 100-tonne plutonium stockpile.

Although the plutonium is reactor-grade material (unsuitable for weapons) it still requires expensive security measures.

The GE-Hitachi proposal would entail operating the two 311 MWe units initially to bring the material up to the highly-radioactive 'spent fuel standard' of self-protection and proliferation resistance. The two PRISM units would irradiate fuel made from this plutonium for 45-90 days, after which is would be stored in air-cooled silos. The whole stockpile could be irradiated in five years, with some by-product electricity (but frequent interruptions for fuel changing).

The plant would then proceed to re-use it over perhaps 55 years solely to generate 600 MWe of electricity. The cost of the plant including fuel preparation would be comparable to a large conventional reactor, according to GE-H, which is starting to develop a supply chain in the UK with Costain, Arup & Poyry to support the proposal and prepare for UK design certification. The reactor design has evolved over some 30 years, and is based on the US EBR-II which operated 1963-94.

Point Lepreau Completes Fuel Channel Installation

In mid November 2011, New Brunsweick Power announced that the Refurbishment Project team has successfully completed the fuel channel installation.

The NB Power and AECL teams continue to work around the clock to complete all project activities in order to complete the retubing activities by May 2012. After the commissioning activities are completed, the Station is expected to return to service by the fall of 2012.

The fuel channel installation activities involved 380 pressure tubes inserted horizontally into the calandria vessel with 760 end fittings (one at each end), spacers, positioning assemblies as well as bellows welding - very complex and precise work.

The fuel channel installation project milestone was achieved ahead of the December 2011 scheduled completion date.

The next major activity is to remove the large work platforms from which the majority of reactor retube activities were conducted. The fuel channel platform is made up of several large beams and columns and its removal is expected to take approximately one month.

Following the fuel channel platform removal the installation of 760 lower feeder pipes will proceed, which is the last major refurbishment activity prior to loading fuel inside the reactor.

In parallel with the platform removal, NB Power is filling the calandria vessel with heavy water.. This parallel activity is one of many that NB Power will complete in preparation for the fuel loading and restart activities.

The major remaining milestones include:

- Lower feeder installation completion (May 2012)
- Return to service and generating electricity (fall 2012)

OPG Submits Documents for Darlington Refurbishment

On December 6, 2011, Ontario Power Generation (OPG) has submitted the *Environmental Impact Statement (EIS) and Integrated Safety Review (ISR)* reports to the Canadian Nuclear Safety Commission (CNSC). The submissions demonstrate positive conclusions in support of refurbishment activities and the continued operation of the Darlington station.

The EIS is comprised of more than 4,500 pages of data contained in sixteen volumes, and represents the culmination of years of detailed studies on and around the Darlington site, including public and community consultation. It concludes refurbishment and continued station operation will not result in any significant adverse environmental effects, given mitigation.

The ISR report, completed over a three-year period and containing more than 10,000 pages, is a comprehensive assessment of plant design, condition and operation.

The ISR report concluded the existing Darlington station demonstrates a high level of compliance with modern codes and standards. The ISR did not identify any issues that would limit safe long-term operation of the station and no gaps were identified that would affect current safe operation.

To ensure the ISR addressed all safety areas, an aggregate assessment was performed by a team of independent nuclear industry experts. The assessment concluded the Darlington station performance is strong, the plant is operating safely and the ISR activities fully meet the requirements the CNSC.

The EIS and technical supporting documents, along with a synopsis of the ISR, are available on the Darlington Refurbishment page of OPG's website at: www.opg.com/power/nuclear/refurbishment/.

OPG announced in February 2010 that it would proceed with the planning for the refurbishment of the Darlington Nuclear station. The decision came after the positive outcomes of initial studies on the plant's condition and continued strong safety and operating performance.

Extended Council Discusses CNS future

On Friday and Saturday, October 21 and 22, 2011, most of the members of the CNS Council gathered with a similar number of representatives of Branches, Divisions and other operations of the Society to examine the current operation and plan for the future.

The event began with a shortened Council meeting on the Friday morning, with about half of the other participants attending.

Following lunch the group met first in a plenary format. In his opening address, President Frank Doyle urged everyone to focus on outcomes. He asked everyone to review the elements of the Strategic Plan that had evolved from the previous special session two years earlier and explore the elements that will enhance the long-term viability of the Society.

He stated that there the major initiatives were: decision on engaging an Executive Director; Branch improvement; and new focus for the Divisions.

After a break, former president Eric Williams presented the evolution of the Strategic Plan that had its genesis in a 2009 8report by Murray Stewart and Bob hemming and developed further in a Special Session held in January 2009. He had coordinated a Working Group that produced a Strategic Plan for 2010 to 2015. That report had been distributed to all participants. A major recommendation was the appointment of an Executive Director.

An active open discussion ensued which touched on a number of questions such as; lack of members from the nuclear utilities; and general lack of awareness of the Society as well as the Executive Director question.

That evening there was a dinner followed by a short talk on the history of the Society by Fred Boyd and presentation of a video on Rutherford, one of three DVDs produced with partial support of the CNS.

On the Saturday morning the focus was initially on Branches, using, as a starting point, a Branch Improvement report prepared by Syed Zaidi. There were short reports from most of the Branches. Then the participants broke up into groups for focussed discussions. After a break a similar process took place about Divisions.

After lunch the President tried to elicit agreement on the various points discussed.

He presented his summary to the December 9, 2011 Council meeting, Following are the major points he identified:

General

- Proceed with ED Initiative
- Provide list of speakers
- Provide easy (financial) transition to full membership (for YGN)

Divisions

- Align activities of O&M and D&M Divisions (e.g. CMC in Year 1, SHRPVC in Year 2)
- Align activities of NSE, FT and FST Divisions
- Align activities of WM and Mining Divisions
- O&M & D&M Division committees include Branch delegates from the nuclear sites,
- Alignment of other Divisions with the appropriate branches

Branches

- Strike new Branch Improvement Initiatives Committee and review and propose for implementation actions arising from Seminar.
- Simplified planning and budgeting processes

CNS to Host PBNC 14

The Canadian Nuclear Society has been officially sanctioned to hold the 19th Pacific Basin Nuclear Conference in August 2014.

The Pacific Nuclear Council, an international body of nuclear societies and associations of countries around the Pacific Rim, unanimously approved the CNS proposal during a meeting held in Washington, D.C. on October 30, 2011 just prior to the ANS Winter Meeting.

PBNC 2014 will be held in Vancouver, August 24-28, 2014.

Given the nature of this major international event, CNS has been in contact with representatives of the major companies and organizations in the country which are involved with the nuclear program and received commitments or promises of support.

Current CNS president, Frank Doyle, has taken a lead in this endeavour and has stated his intention to continue to be very involved after his term of office. Since an international event of this size and importance requires considerable planning, if you, as a CNS member or reader of the Bulletin, would like to be involved, please contact him.

News from Branches

ALBERTA – Duane Pendergast

1) Jason Donev attended the 2011 CNS Officers Seminar in Toronto on behalf of the Alberta Branch. He engaged in sessions and conversations about out what we could do to improve the membership of the CNS and the performance of Branches. This generated questions about what advantage there is in being a member of the CNS. Concern was raised about a need to attract 'young people'. He provided an example based on the success of the Branch trip to INL, highlighting opportunities for senior members of the CNS to interact with new student members during the trip.

   He appreciated the opportunity to talk with others and came back with ideas for Branch activities. In particular he appreciated the Rutherford documentary and discussions with Dr. Emily Corcoran from RMC about education issues and with Eric Williams on the forthcoming EIC climate change technology conference.

   Jason was convinced that we, the AB branch, do need to establish a website to let the public know the kind of activities we are involved with and how they might contact us.

2) Duane Pendergast accepted an invitation from David Layzell of the U of C's Institute for Sustainable Energy, Environment and Economy to participate in an Institute sponsored Conference on the Assessment of Future Energy Systems (CAFES) on November 3, 4, 2011. This was a great opportunity to keep nuclear energy on the agenda of a significant Alberta based conference attended by about 200 people. Duane Pendergast, Shaun Ward, Laurence Hoye and Jason Donev participated in the presentations and discussion. Presentations and discussion are to be posted on the ISEEE website. David Layzell indicated the ISEEE intends to hold this conference every other year.

3) Rob Varty reports that the "ATA Science Conference 2011" was held in The Fairmont Chateau Lake Louise, from October 20 to 22, 2011. Rob helped Paul Hinman with the management of this project. The conference was organized by the Science Council of the Alberta Teachers' Association (ATA). Five members of the CNS (Derek Belle, Aaron Hinman, Paul Hinman, Peter Lang and Rob Varty) worked at the conference. These members operated the CNS display booth on October 21 and 22. Peter Lang presented a workshop on "NORM, Naturally Occurring Radioactive Materials", on October 22, to a group of science teachers. The workshop and the display booth featured Geiger counters with computers. The display-booth personnel received completed Geiger-kit application forms and completed questionnaires from teachers. Seven application forms have been sent to Bryan White for the consideration of the Education and Communication Committee. This conference at Lake Louise had 420 paid delegates. (The previous year's conference in Edmonton had 247 paid delegates.)

CHALK RIVER – Ruxandra Dranga

Speakers:

- The CNS Chalk River Branch held its Branch Annual Meeting on October 27th, 2011. The new CNS - CRB Executive is:

Chair:	Ruxandra Dranga
Treasurer:	Alex Trottier
Program Coordinator:	Ashlea Colton
Education and Outreach:	Bryan White
Communications:	Amir Sartipi
Rad. Program at Algonquin College Liaison:	Mark Branecki
NA-YGN Liaison:	Natalie Sachar
PEO Liaison:	Dave Wilder
Members-at-Large:	Bruce Wilkin, Shaun Cotnam, Rob DeAbreu, Mahsa Jamsaz

- October 27th, 2011 - Pia Dimayuga (Grade 12 student at Mackenzie High School in Deep River) talked about her summer experience as a participant in the Shad Valley Program.
- October 27th, 2011 - CNS movie night "NRU vessel change from 1972". I am currently looking into getting permission from AECL to make the copy of the movie available for other CNS branches that might be interested. I also have a copy of the Chernobyl documentary (~1 hour) and the Three Miles Island documentary (~1 hour) for those interested.
- December 5th, 2011 - Peter Lang, Dunedin Energy Systems Ltd. - "The Urgent Need for Small Modular Reactors in Canada`s North``. This talk was organized in collaboration with the ZED-2 Reactor Physics Winter School. The talk was well attended (over 40 people) and it was followed by a lively Q&A session.

- Future talks / seminars :
  - December 8th, 2011 - Dr. Tony Noble, Director of SNOLAB Institute - “The Neutrino Enigma and Other Dark Matters” (organized in collaboration with the ZED-2 Reactor Physics Winter School)
  - December 13th, 2011 - CNS CRB / NA-YGN CR Chapter - Professional Development Mixer. Speakers / mentors include Bruce Wilkin, Jeremy Whitlock, Gina Strati, Dave Torgerson, Al Melnyk, Bryan White, and Mike Atfield. Event opened only to CNS and NA-YGN members under the age of 35.

CNS - CRB execs, ZED-2 team and guest speaker Peter Lang.

DARLINGTON – Jacques Plourde

There are no activities to report for Darlington in this period. However, in the new year, the Branch will explore the possibility of a merger with the Pickering Branch to form an OPG Branch not only serving the Stations, but also OPG-Nuclear H.O. in Pickering. In addition, the Operating Utility Branches (and not only OPG’s) will ultimately benefit from enhancements of the D&M and O&M Divisions proposed to start in 2012 as a result of our discussions at the Officers’ seminar earlier this month.

GOLDEN HORSESHOE – Kurt Stoll

On September 20, Jean-François Béland, Executive Vice President, AREVA Canada Inc., gave a seminar hosted by the CNS Golden Horseshoe Branch. This was a unique event since we rarely host executives for our seminars. Approximately 25 people attended and Mr. Béland spent a lot of time discussing the financial considerations nuclear operators make when looking at a new reactor. He also discussed AREVA’s presence in Canada.

On October 21/22 Kurt Stoll (Golden Horseshoe Branch Chair) and Adriaan Buijs (GHB Treasurer) attended the CNS Officer’s Seminar at the Marriott Hotel in Toronto. Various CNS policies were discussed and a large number of branch improvement ideas were raised and debated.

On November 21, Kurt Stoll attend a free seminar titled “Journalism 101 for Scientists” hosted by the McMaster School of Graduate Studies. Jim Handman (Executive Producer, CBC’s Quirks and Quarks), Rob Davidson (TV journalist/producer) and Hannah Hoag (science journalist and editor) were the highlight speakers. They discussed how scientists can attract media attention and illustrated how the media industry works so that scientists might be more successful in broadcasting their work and opinions.

Golden Horseshoe Branch is in the process of planning a January seminar with Dr. Victor Snell, titled “Design and Safety of Canadian Nuclear Reactors.” This event was initiated by the Hamilton/Burlington PEO Chapter and they opened the door to GHB as a co-host. An official notification will be circulated in the near future.

MANITOBA – Jason Martino

No activity for the Manitoba branch. Of interest though, an AECL seminar series is being held at Whiteshell Laboratories where the presentations made at the CNS Waste Management, Decommissioning and Environmental Restoration Conference in September are being re-presented to AECL WL staff over three sessions in December.

OTTAWA – Mike Taylor

The Branch has held two meetings so far this year. Members were invited to have dinner with the attendees at the recent Heavy Water Reactor Conference held at the Marriott Hotel and to listen to the address by Frank Doyle.

This initiative was much appreciated.

Two members of the current branch executive have withdrawn due to health or work reasons and we have found two new volunteers to replace them and to provide some succession capacity for some of our present long serving members.

We are also continuing active cooperation with the CNSC and Ottawa University with respect to speaker programs and education opportunities. In addition we are in contact with the Canadian Society of Senior Engineers.

More recently, several members of the Branch attended the Officer’s seminar in Toronto and the Branch will have a role in the new Branch Improvement Committee.

On 17th November we co-sponsored with the CNSC a talk by Arnold Eyre and Don Lawson entitled The Energy Compass. This is the title of a paper by the Canadian Society of Senior Engineers that attempts to rank sources of energy against criteria which contribute to the well-being of Canadians using a weighted voting process.

TORONTO – Paul Gillespie

Past Events

- In 2011, the Toronto branch held 2 public seminars:
  - Peter Ottensmeyer: CANDU Used Fuel "Waste" in Canada: A $36 Trillion Energy Resource in Fast Reactors
  - Jerry Cuttler: Is the Supply of More Nuclear Energy to the People of Ontario Environmentally and Socially Acceptable?

Recent Events

- After many years as Chair of the Toronto Branch, Joshua Guin has relinquished this role.
- Paul Gillespie was endorsed as the new chair of the Toronto Branch at CNS Council Meeting #123 in October.
- A Branch Executive Meeting was held on November 15 to obtain an update from the Toronto Branch representative that attended the CNS Officer's Seminar in October, specifically the discussions related to branch improvement suggestions.
- Planning for 2012 events was initiated in this meeting.

Upcoming Events

- A branch meeting will be held in January, 2012 to fill vacant Branch Executive positions and to finalize plans for 2012.

Future Events

- The Toronto branch aims to hold 4 seminars in 2012
- Get Committee Members active in CNS Conferences (organization)
- Promote the CNS and Toronto Branch and increase local membership

UOIT Branch – Kale Stallaert

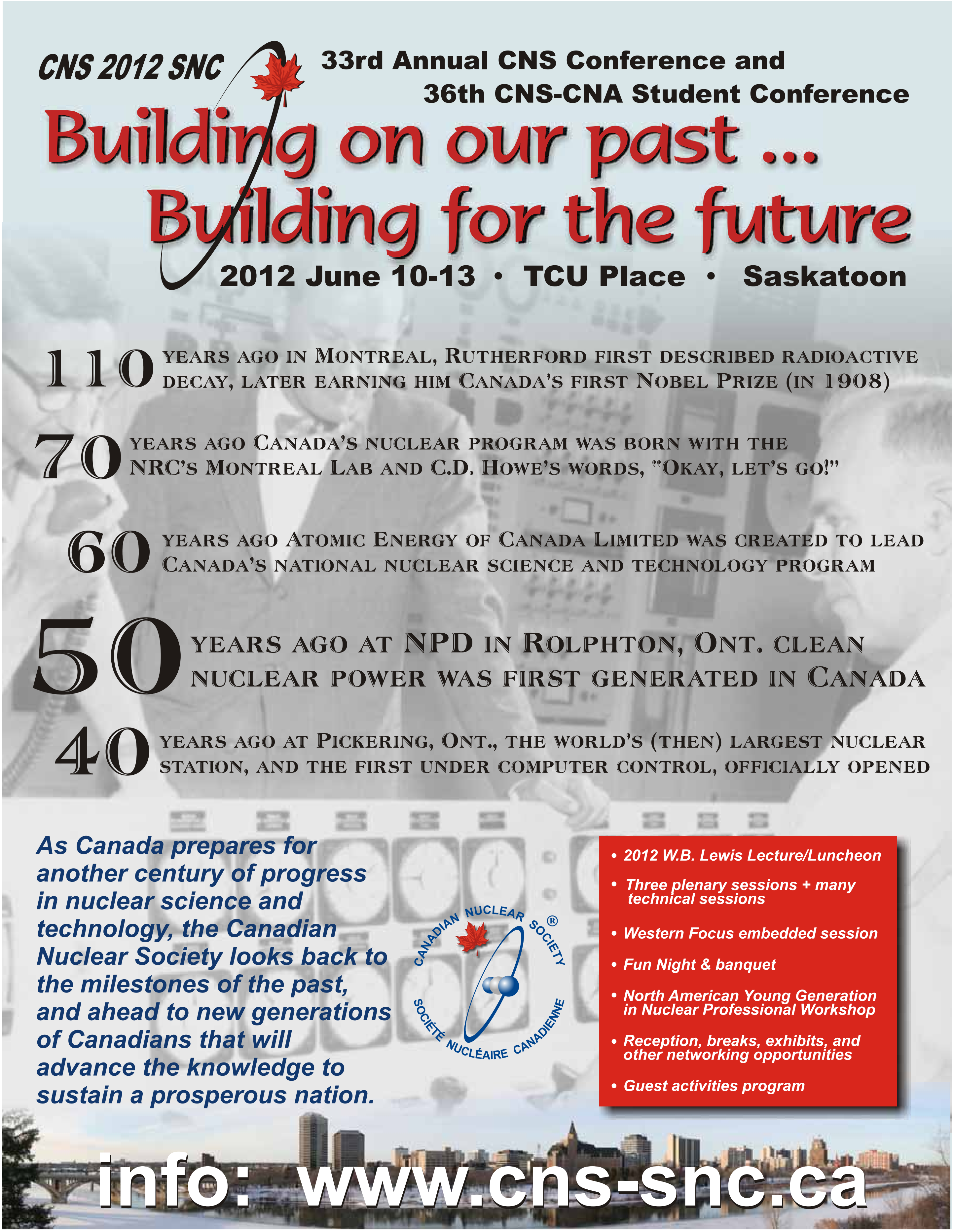
The UOIT Branch has held two technical sessions at the university since September.

On October 24th, Dr. Dan Meneley spoke on the history and design of the fast breeder reactor. 30 students, university professors and other CNS members were in attendance.

On November 21st, The UOIT Branch hosted Dr. Bob Gratsy. Bob spoke on his involvement in Operation Morning Star, the mission to recover radioactive debris from the Russian satellite Cosmos-954 which crashed into the Northwest Territories on January 24th 1978. This event was also very well attended.

Four students represented the CNS – UOIT Branch at the 9th International Conference on CANDU Maintenance, December 4th-6th in Toronto.

As part of its education and outreach program the CNS Chalk River Branch provided Algonquin College, Pembroke Campus, with a portable area gamma monitor for use in the college's Radiation Safety Program. The above photo was taken at a meeting of the college's Radiation Safety Program Advisory Committee, October 25, 2011.
Shown Lto R: Grant Robertson, Acting Radiation Safety Coordinator; Adam,Prescott, Professor; Mark Branecki, Professor; Blair Bromley (with monitor) and Bruce Wilkins, both from the, CNS Chalk River Branch


CNS 2012 SNC
33rd Annual CNS Conference and
36th CNS-CNA Student Conference
Building on our past ...
Building for the future
2012 June 10-13 • TCU Place • Saskatoon
110 years ago in Montreal, Rutherford first described radioactive decay, later earning him Canada's first Nobel Prize (in 1908)
70 years ago Canada's nuclear program was born with the NRC's Montreal Lab and C.D. Howe's words, "Okay, let's go!"
60 years ago Atomic Energy of Canada Limited was created to lead Canada's national nuclear science and technology program
50 years ago at NPD in Rolphton, Ont. clean nuclear power was first generated in Canada
40 years ago at Pickering, Ont., the world's (then) largest nuclear station, and the first under computer control, officially opened
As Canada prepares for another century of progress in nuclear science and technology, the Canadian Nuclear Society looks back to the milestones of the past, and ahead to new generations of Canadians that will advance the knowledge to sustain a prosperous nation.
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• Guest activities program
info: www.cns-snc.ca

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

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

Call for papers

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

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

Objective

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

Topics of interest

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

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

Guidelines for full papers

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

Submission procedure

Submissions of full papers, preferably in MS Word format, must be made electronically through the symposium submission site:

https://www.softconf.com/c/CNS2012Simulation/

Important dates

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

Symposium registration fees (HST included)

	By August 31 / After August 31
CNS Member:	$570/$640
Non CNS Member:	$670 / $740
CNS Retiree Member:	$200 / $240
Full-Time Student:	$200 / $240

Technical program co-chairs

Dr. AdriaanBuijs
Department of Engineering Physics
McMaster University
e-mail: buijsa@mcmaster.ca
Tel.: (905) 525-9140 ext. 24925

Geneviève Harrisson
Institut de Génie Nucléaire
École Polytechnique de Montréal
e-mail: genevieve.harrisson@polymtl.ca
Tel.: (514) 340-4711 ext. 4120

General questions regarding the symposium

CNS Officee-mail: cns-snc@on.aibn.com
Tel.: (416) 977-7620

Notes to Authors

Copyright in papers submitted to the 24th Nuclear Simulation Symposiumof the Canadian Nuclear Society remains with the author and/or with his/her organization, but the CNS may freely reproduce the papers in print, electronic or other forms. The CNS retains a royalty-free right to charge fees for such material as it finds appropriate.

For a paper to be presented at the symposium and to appear in the proceedings, at least one of the authors must register by the early bird date.

Société Nucléaire Canadienne
24e Symposium de Simulation Nucléaire
PROGRÈS DANS LES OUTILS ET MÉTHODES DE SIMULATION

14 au 16 octobre 2012
Hôtel Marriott Ottawa
Ottawa, Ontario, Canada

Appel à contributions


Photo prise à Ottawa le 14 Octobre 2006 (© zen! / Flickr)

La Société Nucléaire Canadienne organise son 24e Symposium de Simulation Nucléaire. Le symposium aura lieu à Ottawa (Ontario, Canada) du 14 au 16 octobre 2012.

Objectif
L'objectif du symposium est de fournir un forum de discussion et d'échange d'informations, de résultats et de points de vue entre les scientifiques, les ingénieurs et les universitaires qui travaillent dans divers domaines dugénie nucléaire.

Sujets d'intérêt
La portée du symposium couvre tous les aspects de la modélisation et de la simulation nucléaire, y compris, mais non limités à:

- Physique des réacteurs
- Thermohydraulique
- Analyses de sûreté
- Combustible et canaux de combustible
- Modélisation et codes de calcul

Lignes directrices pour les articles complets
Les articles doivent présenter des faits nouveaux et importants ou l'état de l'art dans un domaine d'étude. Une exposition claire du sujet devrait être faite en environ 10 pages.Des références doivent être incluses pour toutes publicationsappropriées et étroitement liées au sujet de l'article.

Procédure de soumission
Les articles complets, en format MS Wordde préférence, doivent être soumis par voie électronique à partir du site de soumission du symposium:

https://www.softconf.com/c/CNS2012Simulation/

Dates importantes
Date limite pour soumettre les articles complets:...31 mai 2012
Annonce d'acceptation:...30 juin 2012
Date limite pour soumettre les articles finaux:...... 15 août 2012
Fin de l'inscription hâtive:.....................................31 août 2012

Frais d'inscriptionau symposium (TVH incluse)
Jusqu'au 31 août / Après le 31 août
Membre de la SNC:.............................. $570/$640
Non-membre de la SNC:....................... $670 / $740
Retraité(e) et membre de la SNC:..........$200 / $240
Étudiant(e) à temps plein:......................$200 / $240

Co-présidents du programme technique
Dr. Adriaan Buijs
Department of Engineering Physics
McMaster University
courriel: buijsa@mcmaster.ca
Tél.: (905) 525-9140 ext. 24925

Geneviève Harrisson
Institut de Génie Nucléaire
École Polytechnique de Montréal
courriel: genevieve.harrisson@polymtl.ca
Tél.: (514) 340-4711 ext. 4120

Questions générales sur le symposium
Bureau de la SNC, courriel: cns-snc@on.aibn.com
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Pour qu'un article soit présenté au symposium et pour qu'il paraisse dans les actes du symposium, au moins un des auteur(e)s doit s'inscrire avant l'échéance de l'inscription hâtive.

Calendar

2012

Feb. 22-24 — **CNA Nuclear Industry Conference and Tradeshow**
Ottawa, Ontario
website: www.cna.ca

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

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

Apr. 9-27 — **Seminar and Training to Transfer Knowledge in Scaling Uncertainty and 3D Coupled Code Calculations**
Daejon, Korea
website: www.grnspg.in.unipi.it/3dsuncop

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

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

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

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

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

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

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

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

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

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

2013

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

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

Obituary

Maurice Duret

Dr. Maurice F. Duret, an early scientist at the Chalk River Nuclear Laboratories, died at Deep River, Ontario, on November 23, 2011 at the age of 89.

He was born in Gainesborough, Saskatchewan, in 1922 and attended school in Regina before joining the Royal Canadian Navy in which he served for five years during the Second World War. On returning he attended Queen's University then moved to the University of Toronto where he obtained a Ph.D. in 1952, and immediately joined the newly formed Atomic Energy of Canada Limited at CRNL.

He first joined the Reactor Physics Branch which was part of the Reactor Research and Development Division. One of his activities was analysing the optimum thickness of a graphite reflector on a heavy water moderated core. A few years later he was named head of the Applied Mathematics Branch when it was created.

His funeral was held November 25 in the Chapel of the Valley Funeral Home, with interment at the Beechwood Cemetery in Ottawa on November 26.

A Mediated Interaction By Any Other Name

by Jeremy Whitlock

SEATTLE, WASHINGTON: The International Physics Union (IPU) announced today that it will be seeking new names for the Weak and Strong Nuclear forces. The decision was made at the IPU's annual conference, following a lively debate on the pros and cons of updating the decades-old terminology.

"These are basically silly names," explains IPU President Horst Mulegger. "Clearly there wasn't a lot of thought put into them at the time. We can't blame our predecessors really ... it was a busy time, what with quarks and gluons and heavy bosons taking all their attention."

"In the early days they had more time for naming fundamental forces: gravity, electromagnetism... Talk about firing the imagination! Catching your attention! But 'strong' and 'weak'? And then abominations like 'electroweak' come along, once the forces start getting unified... I tell you, it's like watching a train wreck."

But the time has come to correct that, Dr. Mulegger points out.

"These days communication is everything. We got to thinking: why are people so afraid of radiation, and nuclear power? These concepts are no more complicated than, say, spaceflight, and yet people aren't kept up at night worrying about spaceflight."

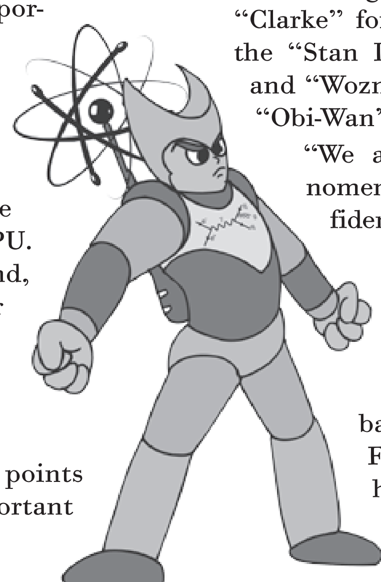
The answer, according to the IPU, is all in the name.

"Everything is physics," Mulegger asserts, "including public communication. So we put our best minds together and came up with the solution. It was quite obvious actually: change the name of the nuclear forces; change the attitude of the public."

The IPU's news release explains further how both types of nuclear forces are of utmost importance to life on this planet, not just in holding everything together (literally) but also in releasing energy that sustains us all.

Nuclear power is basically the unleashing of the Strong Nuclear force for the good of humanity, according to the IPU. The Weak Nuclear force, on the other hand, is responsible for everything from our Sun's warming rays, to the geothermal heat in the earth's core that maintains the planet's magnetic field and protects us all from deadly cosmic radiation.

"Those are some hefty responsibilities", points out Dr. Mulegger, "so why give such important forces of nature such dumb names?"



The question, then, is what to name them. The IPU is certain its membership will come up with some creative ideas.

"Physicists are very innovative people. They like to think outside the sphere."

Some suggestions have already started to trickle in. Dr. Mulegger himself has started the ball rolling.

"I'm partial to 'Bilbo' and 'Frodo' Forces, respectively", he says proudly. "Everyone likes hobbits. They're cuddly but tenacious, and they tend to come through in the end and save the world."

Is the world ready for Bilbo power stations, Frodo-powered PET scanners, and can Samwise, Pippin, and Meriadoc technology be far behind?

Mulegger laughs off this suggestion.

"That's getting a tad facetious. Although, the idea of a 'Gandalf' grand unifying theory has a certain appeal."

How supportive does the IPU expect the world's scientific community to be of its decision to rename a couple of forces that generations have grown up with?

"There's bound be a few stuck in the old ways", agrees Mulegger, "You should see the tussles that still take place over the IAU's demotion of Pluto to dwarf planet. And the hullabaloos over superstring D-branes, Higgsless models, and whether Han Solo shot Greedo first ... don't get me started."

"But particle physics is very colourful to begin with. Quite literally in fact. It's actually somewhat inconsistent to give these particularly prominent agents of nature such mundane labels."

Other suggestions to date include the "Asimov" and "Clarke" forces, the "Lucas" and "Spielberg" forces, the "Stan Lee" and "Bob Kane" forces, the "Jobs" and "Wozniak" forces, and, of course, "Anakin" and "Obi-Wan".

"We are certain society will embrace whatever nomenclature we settle on," adds Mulegger confidently, "and then widespread support for globally sustainable nuclear technology will grow in leaps and bounds."

Mulegger gazes wistfully out his office window.

"And children everywhere will dream of bathing in femtometre-scale Bilbo-generated Frodo rays to turn themselves into superheroes."

No doubt some are doing this already.

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President / *Président*	F.W. (Frank) Doyle	416-595-1888 x156
e-mail	frank.doyle@candu.org	
Past President / *Président sortant*	A. (Adriaan) Buijs	905-525-9140 x24925
e-mail	adriaan.buijs@sympatico.ca	
1st Vice-President / *1ier Vice-Président*	J.G. (John) Roberts	519-361-5898
e-mail	alchemy@tnt21.com	
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e-mail	winc@mts.net	
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e-mail	mohamed.younis@amec.com	
Secretary / *Secrétaire*	C.G. (Colin) Hunt	613-742-8476
e-mail	colin.hunt@rogers.com	
Financial Administrator / *Administrateur financier*	K.L (Ken) Smith	905-828-8216
e-mail	unecan@rogers.com	
Executive Administrator / *Administrateur exécutif*	B. (Ben) Rouben	416-663-3252
e-mail	roubenb@alum.mit.edu	

Members-at-Large / *Membres sans portefeuille*

Parva Alavi	905-823-9060
Parvaiz Akhtar	613-837-9846
Emily Corcoran	613-541-6000 x6510
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David Novog	905-525-9140 x24904
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Jad Popovic	905-820-7472
Ben Rouben	416-663-3252
Natalie Sachar	613-584-8811 x46236
Nick Sion	416-487-2740
Gordon Tapp	613-584-3311
Ken Smith	905-828-8216
Jeremy Whitlock	613-584-8811 x44265
Syed Zaidi	613-584-3311 x43692

CNS Committees / *Comités de la SNC*

Program / Programme
Len Simpson ... 204-753-8334 winc@mts.net

CNA Interface / Interface avec l'ANC
Dietwald Claus, CNA ... 613-237-4262 x109 dietwaldc@cna.ca

WiN Interface / Interface avec WiN
Jad Popovic ... 905-820-7472 popovic@rogers.com

Branch Affairs / Chapitres locaux
Syed Zaidi ... 613-584-3311 x43692 smh@zaidi.net

Education and Communications / Éducation et communications
Peter Lang ... plang@drlogick.com
Jeremy Whitlock ... 613-584-8811 x44265 whitlockj@aecl.ca

Membership / Adhésion
Ben Rouben ... 416-663-3252 roubenb@alum.mit.edu

Finance / Finances
Mohamed Younis ... 416-592-6516 mohamed.younis@amec.com

Past Presidents / Anciens présidents
Adriaan Buijs ... 905-525-9140 x24925 adriaan.buijs@sympatico.ca

Honours and Awards / Prix et honneurs
Kris Krishnan ... 905-997-7797 sankrish@rogers.com

International Liaison / Liaisons internationales
Kris Mohan ... 905-332-8067 mohank@sympatico.ca

Internet / Internet
Ben Rouben ... 416-663-3252 roubenb@alum.mit.edu

Inter-society Relations / Relations inter-sociétés
Adriaan Buijs ... 905-525-9140 x24925 adriaan.buijs@sympatico.ca

Young Generation / Jeune génération
Natalie Sachar ... 613-584-8811 x46236 sacharn@aecl.ca

Representative to PAGSE / Représentant auprès de PAGSE
Fred Boyd ... 613-592-2256 fboyd@sympatico.ca

Appointed to Council

Parvaiz Akhtar ... 613-837-9846

Technical Divisions / *Divisions techniques*

- Nuclear Science & Engineering / Science et génie nucléaires
  Elisabeth Varin 514-875-3476 varine@aecl.ca
- Fuel Technologies / Technologies du combustible
  Steve Palleck 905-823-9060 x34542 pallecks@aecl.ca
  Erl Køhn 416-592-4603 erl.kohn@amec.com
- Design and Materials / Conception et matériaux
  John Roberts 905-403-7585 alchemy@tnt21.com
- Environment & Waste Management / Environnement et gestion des déchets
  Ken Dormuth 905-569-2306 kwdormuth@rogers.com
- Nuclear Operations & Maintenance/ Exploitation nucléaire et entretien de centrale
  Jacques Plourde 905-441-2776 jap-performance@rogers.com
- Mining and Processing / Travaux de mine
  John Roberts 905-403-7585 alchemy@tnt21.com
- Medical Applications and Radiation Protection/Applications médicales et protection contre les rayonnements
  Tony Waker 905-721-8668 x2968 x3441 anthony.waker@uoit.ca
- Fusion Science and Technology / Scjence et technologie de la fusion
  Blair Bromley 613-584-3311 x43676 bromleyb@aecl.ca

CNA Liaison / *Agent de liaison avec l'ANC*

Dietwald Claus 613-237-4262 x109 dietwaldc@cna.ca

CNS Bulletin Publisher / Éditeur du Bulletin SNC

Fred Boyd 613-592-2256 fboyd@sympatico.ca

CNS Bulletin Editor / Rédacteur du Bulletin SNC

Ric Fluke 416-592-4110 richard.fluke@amec.com

CNS Office Manager / Administratrice du bureau de la SNC

Denise Rouben 416-977-7620 cns-snc@on.aibn.com

Branches / Chapitres locaux

Alberta	Duane Pendergast	403-328-1804 still.thinking@computare.org
Bruce	John Krane	519-361-4286 john.krane@brucepower.com
Chalk River	Ruxandra Dranga	613-717-2338 drangar@aecl.ca
Darlington	Jacques Plourde	905-441-2776 jap-performance@rogers.com
Golden Horseshoe	Kurt Stoll	905-525-9140 stollkj@mcmaster.ca
Manitoba	Jason Martino	204-753-2311 x62229 martinoj@aecl.ca
New Brunswick	Brad Nash	bradnash247@gmail.com
Ottawa	Mike Taylor	613-692-1040 cosmot@rogers.com
Pickering	Leon Simeon	905-839-1151 x2520 289-314-9014 leon.simeon@opg.ca
Québec	Michel Saint-Denis	514-875-3452 Michel.Saint-Denis@candu.com
Saskatchewan	Walter Keyes	306-586-9536 Walter.Keyes@sasktel.net
Sheridan Park	Peter Schwanke	905-823-9040 Peter.Schwanke@candu.com
Toronto	Paul Gillespie	416-217-2445 paul.gillespie@amec.com
UOIT	Kale Stallaert	905-436-7161 kale_stallaert@rogers.com

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