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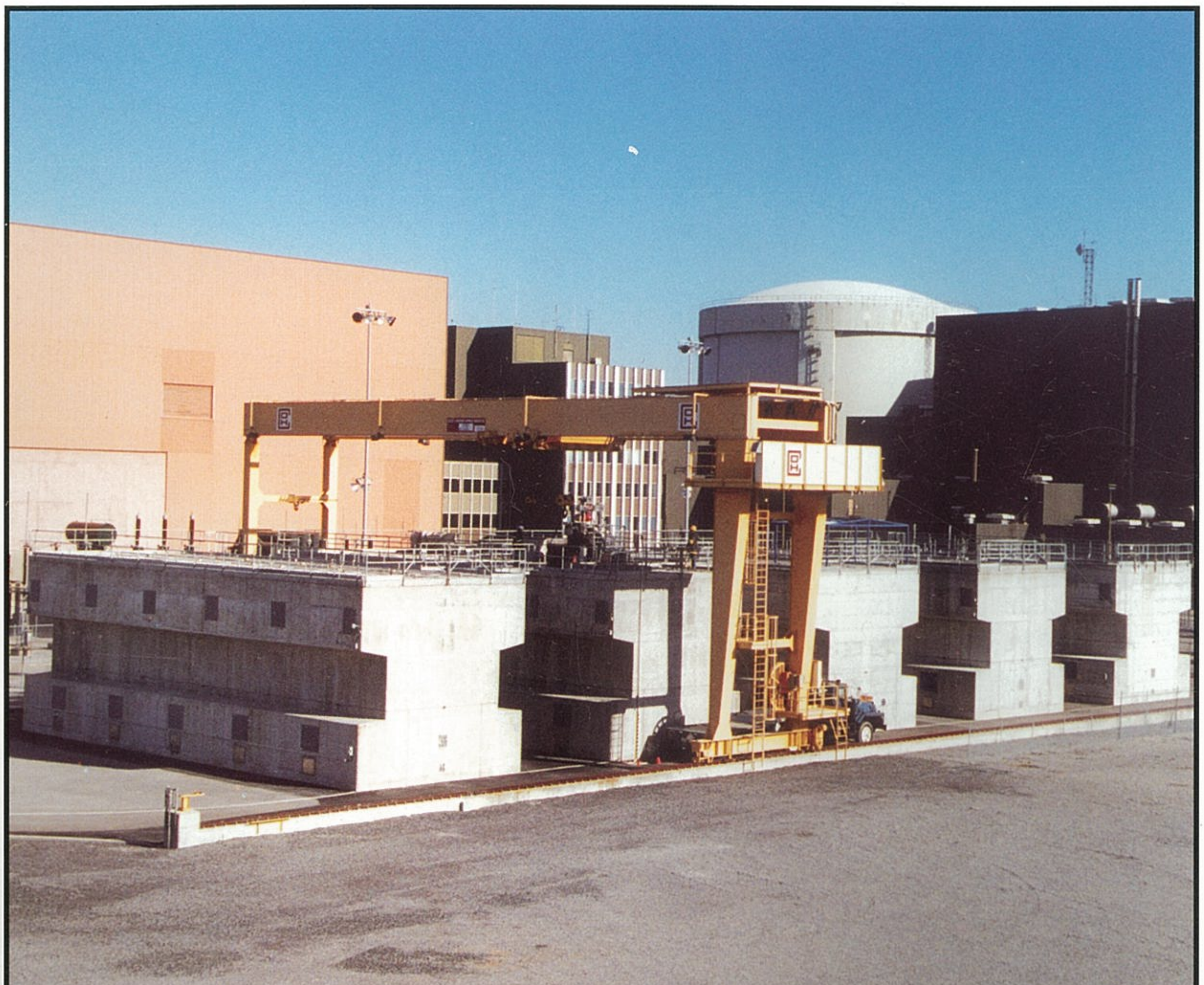

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Cover Photo

The cover photograph shows the MACSTOR facility at the Gentilly-2 nuclear generating station, which is very similar to one just completed at the Cernavoda site in Romania.

(Photo courtesy of Atomic Energy of Canada Limited)

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

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La SNC procure aux Canadiens intéressés à l'énergie nucléaire un forum où ilf peuvent participer à des discussions de nature technique. Pour tous renseignements concerant les inscriptions, veuillez bein entrer en contact avec le bureau de la SNC, les membres du Counseil ou les responsables locaux.
La cotisation annuelle est de 65.00$, 40.00$ pour les retaités, et san frais pour les étudiants.

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EDITORIAL

A Need for Openness

This is being written just over a week after the great "blackout" of August 14 when the electricity system of Ontario and northeastern USA suddenly failed.

In the days after the event the behaviour of nuclear power plants became a topic for distorted, often extreme, criticisms, especially about our Canadian nuclear generating stations. This began on the day after the event with a completely unwarranted, and, in our view irresponsible, comment by a federal Minister, that the power failure was triggered by an event in a nuclear plant in Pennsylvania.

At the time of writing the initiating cause appears to have been failures associated with a generating plant in Ohio, but why the northeastern grid failed is still a mystery. (As an aside, we were at a meeting just about a year ago in which the strength of the system was extolled.)

Here at home the media gave great coverage and credence to several "experts", all with well-known anti-nuclear attitudes, who provided much disinformation about why Ontario's nuclear plants "failed" and the "problems" with nuclear plants in general and CANDU in particular. Several knowledgeable members of the CNS responded to the papers but none of their letters were published or acknowledged.

Unfortunately the organization with the most nuclear plants was silent. Nothing was heard from Ontario Power Generation for a week. Even its website went down. When OPG did speak it came clear that just one unit at Darlington was put into "standby" mode and available in the hours after the event. The other three at Darlington and all four at Pickering B shut down (or tripped) and poisoned out, meaning they were not available for days. The reason remains unclear.

On the other hand Bruce Power managed to put three of their four operating units into "standby" mode and have them available for generation within hours. Further, they announced that on their website the next day.

The difference in behaviour suggests that it is not the technology that is at fault.

To correct all of the disinformation and, more importantly, to learn from our mistakes and move forward, there needs to be full disclosure of what happened and discussion of how to improve things for the future.

Undoubtedly many involved will try to evade such openness, fearing repercussion. That is understandable. But, an objective review does not need to lay blame, just focus on causes and how to improve the overall operation of our nuclear plants. That is essential if we are to achieve a high standard of operation of our nuclear plants and maintain the public's acceptance of nuclear power.

Fred Boyd

IN THIS ISSUE

Much of this issue is drawn from the 24th CNS Annual Conference held in Toronto, June 8 - 11, 2003 and the related presentation of what are now termed "Nuclear Achievement Awards". The selection of papers from the Conference is, admittedly, quite arbitrary, based on our judgement of what would have relatively broad interest among our readers

We begin, though, with two letters, responding to, or building on letters in the previous issue, which we urge you to read. Our "Letters" pages are there for your comment on any matter related to the Canadian nuclear program.

The first article is our report on the **24th CNS Annual Conference,** followed by a full coverage of the many recipients of this year's **Nuclear Achievement Awards.** The contributions of all those recognized is impressive.

Next is the first of several items from the conference, the talk by Larry Foulke, president of the American Nuclear Society on **Nuclear Power in the USA.** That is followed by one of the technical papers on an important development, **Open Top Construction on the Qinshan Project.**

A paper from one of the plenary sessions at the Conference presents an interesting possibility, **Opportunities for CANDU for the Alberta Oil Sands.** That is followed by an insight into one of the major challenges in refurbishing a CANDU plant in **Retubing Point Lepreau.** Then, touching on the important human component, there is a paper on a proposed approach to one aspect of training in **Reactor Safety Training for Decision Makers.**

Leaving the Conference, there is a paper on the Canadian participation in an interesting study, **The OECD Pipe Failure Data Exchange Program.**

There is the usual eclectic selection of items in **General News** and several pieces in **CNS News,** including a longer than usual introduction to the new president of the Society for 2003 - 2004, Jeremy Whitlock, in **Meet the President.**

Rounding out the issue is a page on **Books,** an updated **Calendar,** and, of course, Jeremy Whitlock's unique view of affairs in **Endpoint.**

Your reactions, comments, whatever, are always appreciated.

The Environment Must Be Protected

Dr Cutler advises the CNS to take a stand against the introduction of new regulations to protect the environment from human-made radiation (see Vol. 24. No 2 Issue of the CNS Bulletin). This is not sound advice. The nuclear industry is already seen by many (unjustly I believe) in a negative light with respect to the environment. Asserting that it need take no heed of the possibility of impacts on biota from nuclear operations, if humans are adequately protected, would only reinforce this view.

In fact the industry can gain environmental credibility by showing through actual environmental assessments – as many facilities are already doing – that radiation dose rates to biota from operating or waste facilities are below values at which detrimental effects on biota populations might be expected. Such values are about 3 mGy/d or 1 Gy/a according to UNSCEAR in its 1996 report [1]. Although there is some debate internationally on the precise values to be adopted as criteria for effects on biota, values chosen tend to be on the order of 1 Gy/a. Note that such values are not insignificant compared with natural radiation levels as Dr Cutler asserts. Comparing doses to humans from nuclear power plants with those from natural radiation, as Dr Cutler does in his Figure 1, is a red herring in the context of environmental protection. *(An apposite metaphor?)* Actual doses and dose rates to biota from emissions are the relevant quantities; in some circumstances these can be much higher than those to humans.

In his discussion of the beneficial effects of radiation on organisms, Dr Cutler misses the point that ecosystems are biota battlefields. Enhance one organism and others lose out. If we accept the basic principles of protection as suggested by the IAEA [2], namely, sustainability of the environment, maintenance of biodiversity and conservation of habitats, then we should be trying to avoid undue perturbation of ecosystems, whether by detrimental or beneficial effects on particular ecosystem components. It is change that matters. This point has been made before – for example in the 2002 ACRP report [3]. Hence, taking the occurrence of hormesis in some ecosystem components as a reason for not considering protection of the environment is another red herring. *(Perhaps not such an apposite metaphor this time!)*

The major need is for any environmental protection regulations and licensing conditions that are established in Canada under the Nuclear Safety Act to be regarded as reasonable by the industry, by the regulator and by the public. This desirable end will not be achieved by the industry denying that any regulations or conditions concerning environmental protection are needed.

Richard Osborne

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1. United Nations Scientific Committee on the Effect of Atomic Radiation. *Sources and Effects of Ionizing Radiation: 1996 Report to the General Assembly; Annex: Effects of radiation on the environment.* United Nations, New York 1996.
2. International Atomic Energy Agency. *Ethical Considerations Protecting the Environment from the Effects of Ionizing Radiation.* IAEA-TECDOC-1270, IAEA, Vienna 2002.
3. Advisory Committee on Radiological Protection. *Protection of Non-Human Biota from Ionizing Radiation.* Canadian Nuclear Safety Commission INFO-0730, CNSC, Ottawa 2002.

Richard Osborne was formerly Director of Health and Environmental Sciences at Atomic Energy of Canada Limited. He now directs Ranasara Consultants Inc.

Need Review of Nuclear Program

I support, and extend beyond the nuclear industry, Jim Harvie's call for PI R2 – an all round Politically Incorrect Radical Review of some negative aspects of Canada's nuclear program (CNS Bulletin, 24, 2, 2003 May, p.2).

As former Scots we illustrate John Kenneth Galbraith's words, *"If a man didn't make sense, the Scotch (sic) felt it was misplaced politeness to try to keep him from knowing it. As a result I have rarely managed to avoid telling the intellectually obtuse what I feel they ought to know."*

Harvie refers to problems with the MAPLE project.

A year ago I wrote to the President of the Canadian Nuclear Safety Commission (CNS Bulletin, 23, 2, 2002 May, p.2), stating: *"I attribute much of the delay to the failure of the CNSC (including its predecessor the AECB) to publish regulatory documentation appropriate to reactors that do not produce electric power: and to AECL's proceeding to design and construction of the reactors in the absence of such documentation".* The CNSC's website still shows no relevant documentation.

Harvie also refers to Ontario Hydro's (OH) problem in 1997 that led to the temporary shutdown of two nuclear stations, the recruitment of U.S. "experts" to restructure the organization and the subsequent delays in returning Pickering-A to service. In my 1997 submission to the Ontario Legislature's Select Committee on OH Affairs, "Nuclear Degeneration", I argued that the responsibility for OH's degeneration must extend to the highest levels of the organization at the time, and even beyond. The Independent, Integrated Performance Assessment Report, was commissioned by, and reported to, OH management and so did not identify problems within the OH Executive and Board, and the government.

I would go further back still, to the escalation in costs of the Darlington Station, for which the industry is usually blamed. I admit that some of this was due to weaknesses in the technology and management, e.g., the fuel vibration problem, but other factors were involved, including weakness in the regulator, unforeseen inflation and political direction.

What I would like to see is a scholarly, non-partisan, critical review of the technical, institutional and political factors that led to these failures. This would be more along the lines of an inquest to establish facts and derive lessons, than a trial to lay blame. As Harvie says, *"Successful industries... learn from their negative experiences"*, and even regulators and governments may learn from theirs.

J.A.L. Robertson

Archie Robertson is a former senior researcher at the Chalk River Laboratories of Atomic Energy of Canada Limited.

24th CNS Annual Conference

Conference Focuses on Nuclear Power

Despite the SARS crisis in Toronto, which almost derailed it, the 24th Annual Conference of the Canadian Nuclear Society came off successfully, drawing an attendance of almost 300 to the Marriott Eaton Centre Hotel, June 8 to 11, 2003.

A successful innovation this year had the 28th Annual CNS/CAN Student Conference embedded in the program of the Annual Conference. There were considerably more student papers than in recent years and there was a respectable audience for their presentation.

Although the program was devoted mostly to nuclear power there were updates on the uranium and radioisotope sectors.

Repeating the arrangement of the previous year the "Nuclear Achievement Awards", chosen by a committee representing both the Canadian Nuclear society and the Canadian Nuclear Association, were presented during the conference banquet on the Tuesday evening. By presenting the awards between courses of the dinner, with interludes of music, the recipients were properly recognized and the evening went off smoothly. *(See the separate article on the Awards.)*

Following tradition the conference began with a pleasant reception on the Sunday evening. The "working" part of the conference began early Monday morning with the opening plenary session on *"Overseas and Domestic Opportunities"* led off with an uplifting and fascinating account of the Qinshan project by **Ken Petrunik,** a vice-president at Atomic Energy of Canada Limited and project head with a presentation titled *"Construction of CANDU in China: A China - Canada Success Story"*. He reported that, through innovative construction techniques and great team effort, both units had been completed ahead of schedule and within budget. *(See Vol. 23, No. 4, November 2002 issue for an earlier version of Petrunik's presentation and the paper "Qinshan CANDU Open Top Construction" in this issue.)*

Next was a paper by **Bal Kakaria** of AECL on *"Value-Added Services to CANDU Plants"*, in which he outlined the many services AECL was offering to assess plants and extend their life. In a paper entitled "Additional Nuclear Capacity for Finland", **Ahti Toivola** of TVO, showed the way to building new nuclear plants. Four shorter papers were presented on new reactor designs:

- AECL's ACR by Jerry Hopwood of AECL
- AP 1000 by Steve Walls of Westinghouse
- Advanced Reactor by Gregg Hudson of Framatome ANP
- ABWR and ESBWR by Atambir Rao of General Electric

Rounding out the session was a panel discussion on *"Potential Markets for Advanced Reactor Designs"* with most of the speakers participating.

At the luncheon the first day, **Larry Foulke,** newly appointed president of the American Nuclear Society, presented an ANS Nuclear Historic Landmark Award for NPD to Lorne McConnell, former vice-president of Ontario Hydro and first superintendent of NPD, the first nuclear power plant in Canada. Foulke also gave a talk on the *"Status and Future of Nuclear Power in the USA"*, excerpts of which are printed elsewhere in this issue.

That afternoon saw the first of the technical part of the program, including the first of the three-part Student Conference. The four parallel technical sessions were titled *"The Future"; "Safety I"; Control Room/Operations I";* and *"Physics"*, each with six papers.

Late that afternoon there was the CNS Annual General Meeting, the sixth since the Society was incorporated in early 1998. *(See a separate report on the AGM in the CNS News section of this issue.)*

The Student Conference and technical session continued the next morning. This time there were five technical sessions: *"Plant Aging and Life Extension"; "Probabilistic Safety Assessment"; "Control Room/ Operations II"; "Reactors and Components I"; "Thermalhydraulics and Radiation"*

During lunchtime the North American Young Generation Network held a special "Professional Development Seminar. **Mark McIntyre,** of Atlantic Nuclear Services, spoke of the activities of the Network under the title of *"NA-YGN - Making a Difference"*. He was followed by a fascinating talk and demonstration by **Chip Horton,** a senior vice-president with General Physics Corporation, on *"Training in Today's Nuclear Environment"* in which he had many of the audience participate in an illuminating experiment in team effort.

The afternoon of the second day returned to the plenary format, under the theme of *"Current Issues and Future Developments"*, beginning with an update by **Elisabeth Dowdeswell,** president of the Nuclear Waste Management Organization, entitled *"Recent Developments and Future Plans re Nuclear Waste Management in Canada"*. She was followed by Grant Malksoske, vice-president of MDS Nordion who titled his update on the radioisotope field *"Advancing Global Health through Innovation"*. **Linda Keen,** president of the Canadian Nuclear Safety Commission, provided a regulatory perspective of Safety Culture.

After its president **Bill Clarke** reviewed recent activities of the Canadian Nuclear Association, Jerry Hopwood, of AECL, spoke on *"Opportunities for CANDU for the Alberta Tar Sands". (That paper is reprinted in this issue of the* CNS Bulletin.)

A comprehensive overview of past and present situation of uranium mining was provided by **John Britt,** of Cameco Inc., in his presentation entitled *"Evolution of the Uranium Market".* He closed with an update on the flooding problem at the McArthur River mine (which is now back into production). *(See report in Vol. 24, No. 2 issue of the* CNS Bulletin.)

Murray Stewart, president of Iter Canada Host Inc., reported on the status of international negotiations for the siting of the ITER project. Four sites have been offered: Clarington (next to the Darlington NPP); Rokkasho in northern Japan; Vandellos, Spain and Cadarache, France. The "high-level" political decision is scheduled. Stewart commented that although the Canadian site has been judged the judged the best technically, the Canadian bid suffers from the lack of support by the federal government and the cancellation of our fusion program.

Don MacKinnon, of the Power Workers Union, spoke about how the PWU was supporting the nuclear industry through advanced labour relations, equity participation (in Bruce Power) and innovative programs for training.

Closing out the afternoon session, **John Root,** National Research Council, gave a review of *Canada's Neutron Beam Laboratory* that NRC operates at the NRU reactor at AECL's Chalk River Laboratories. Neutron scattering has wide applications in industry, medicine, information technology and other fields, he noted. There is a pressing need, he said, for a "modernized" neutron source, such as the proposed Canadian Neutron Facility, to replace the aging NRU reactor.

The evening of the second day was devoted to the Nuclear Achievement Awards Banquet. *(See separate report.)*

The plenary format continued on the morning of the third day, with the theme *"Utility Reports and Future Expectations"* with presentations by representatives of each of the nuclear utilities.

Pierre Charlebois, vice-president at Ontario Power Generation, began with *"OPG Nuclear Performance - Status and Outlook".* He divided his talk into three parts: operating plant performance; update on Pickering A restart; and considerations on life extension. In 2002 Darlington had a Nuclear Performance Index of 91.8 compared to the USA average of 95.4. Pickering B, however, was 73.1. He stated that the first unit of Pickering A, unit 4, is scheduled to start in July. "We now have a more complete understanding of the scope and work sequence", he commented, adding that OPG had taken over the full responsibility for managing the restart project. On life extension Charlebois said that with no renewal all OPG nuclear plants would be phased out between 2012 and 2023, The necessary investment to refurbish OPG's nuclear plants is still being studied, with a need for decisions between 2006 and 2008. Later, when asked why the long delay in restarting Pickering A, Charlebois acknowledged that the project had not been structured properly and that there had not been an integrated approach. He, and Rod White of NB Power, also commented that the Canadian nuclear industry does not, at this time, have the capability to support rehabilitation of all of our nuclear power plants.

Next was **Ron Mottram,** vice-president Bruce A at Bruce Power, who began with a concise review of the first two years of Bruce Power including the re-organization after British Energy withdrew in a presentation titled *Bruce Power - The First 24 Exciting Months.* Then he outlined the

Larry Foulke, president of the American Nuclear Society, shakes hands with Ben Rouben, past president of the CNS, while Lorne McConnell looks on during the presentation of an ANS Historic Landmark Plaque for NPD, Canada's first nuclear power plant.

Bruce A restart program, which has involved 47 different projects. At the time of speaking he reported that fuel was loaded into unit 4 and startup was scheduled for July.

Rod White, vice-president NB Power, reviewed the operation of the Point Lepreau station, which, he reported, had a lifetime capacity factor of 83%. The pressure tubes are now considered to be at 75% of their life. Although he stated that refurbishment of the plant was critical for electricity supply in the province and to meet environmental goals, there is not a compelling business case. Nevertheless, he was followed by **Rod Eagles** who outlined the detailed plan for refurbishment of Point Lepreau, which would take about 18 months with a current target of 2007 / 2008.

Another possible refurbishment was reported by **René Pageau** of Hydro Québec. The first phase of a study to assess refurbishment of Gentilly 2 has been completed and will be presented to the Board of Directors of HQ this fall. It involved over 200 individual studies. The target date for the refurbishment, if approved, is 2008 - 2010, with the objective of obtaining an additional 25 years or more of operation.

A view from overseas was provided by **Qamrul Hoda** of the Pakistan Atomic Energy Commission who titled his paper *"Plant Life extension of a First generation CANDU Plant (Kanupp)"*. Kanupp, which was designed and built by Canadian General Electric, began service in 1972. It was shutdown in December 2002 to make safety upgrades and conduct refurbishment of major components to extend the life of the plant another 15 years. Although the plant is 30 years old it has operated only 11 equivalent full power years, partially because of the grid. The pressure tubes and feeders have been inspected and shown to be in good condition.

The morning session closed off with a panel discussion on *"Open Electricity Market, Decontrol and Privatization"* with participants; **Bruce Campbell** of the Independent Market Operator, **Bruce Boland** of OPG, and **Andrew Johnson** of Bruce Power. Campbell noted that there were peaks in demand both in the summer of 2002 and in January of 2003. At both times there was considerable generation unavailable, as much as 10,000 MW in the fall of 2002 and spring of 2003. The average price over the year was $62 / MWhr (6.2 cents/kwhr). He also noted that almost all of the existing capacity will reach its nominal life in 30 years. Johnson basically endorsed Campbell's warning about capacity. Boland spoke of new generation to be built by OPG, including a windmill at Bruce, gas fired plants at Windsor and Toronto and additions at Niagara. He closed with a pitch for OPG's "Green Power" program.

At the luncheon on the third day the Canadian Nuclear Association presented its International Award to **Dr. Robin Jefferies,** former head of British Energy and of Bruce Power. Jefferies responded with a talk that began with a reference to his coming to Canada in 1997 to create a subsidiary of British Energy which subsequently leased the Bruce nuclear stations from Ontario Hydro. With particular reference to Finland he spoke about five issues which he believed determined whether or not new nuclear plants would be built. These are: excellent operation of existing plants; provision for waste management; a willing "host" community; a supportive and rational national policy; and availability of funding. In each of these areas Finland has been successful. On funding he noted that the TVO utility was a cooperative of many industries and municipalities who put up the capital and received electricity at cost.

The last afternoon had the third part of the Student Conference and four parallel technical sessions: *"Advanced CANDU Reactor"; "Safety II"; Control Room/ Operations III";* and *"Reactors and Components II"*. Shortly after the close of the Student Conference the judges announced the winners: Undergraduate: **Olivier Carrière;** Masters: **Marc Desormeaux;** Doctorate: **Amy Lloyd.** *(Their winning papers are enclosed as a supplement to this issue of the* CNS Bulletin.)

The conference was organized by a large committee headed by Kevin Routledge, of Nuclear Safety Solutions, as chair and Walter Thompson, also of NSS, as executive chair. Others on the committee were: Ken Smith; Ian Wilson; Martyn Walsh; Eleodor Nichita; Roman Sejnoha; Mike Gabbani; Ed Hinchley; Jad Popovic; Patrick Reid; Hugues Bonin; Marc Kealey; Ben Rouben; Andrew Lee; Jeremy Whitlock; Denise Rouben; Denise Brien; Carmen Vasilescu; Veena Sharma; Marlene Thomas; Sanela Turkanovic.

The following companies and organizations associated with the Canadian nuclear program made the conference financially possible through their sponsorship: Atomic Energy of Canada Limited; Bruce Power; Cameco; Canadian Nuclear Association; Framatome ANP; GE Canada; Hydro Québec; MDS Nordion; NB Power; Nuclear Logistics Inc.; Nuclear Safety Solutions; Ontario Power Generation; Organization of CANDU Industries; Power Workers' Union; RCM Technologies; The Society of Energy Professionals; Summit Controls Ltd.; Wardrop; Zircatec Precision Industries Inc.

The conference ended with a call to plan to attend next year's event, to be held June 6 - 9, 2004 in Toronto.

A CD containing all of the presentations given at the 24th CNS Annual Conference is available from the CNS office.

Scenes from the opening reception of the 24th CNS Annual Conference

Nuclear Achievement Awards

The Canadian Nuclear Community Recognizes Major Contributors

Ed Price

There is something special about being recognized by your peers. That is what happened to a select group of people on June 10, 2003 at the Canadian Nuclear Achievement Awards banquet held the second day of the 24th Annual Conference of the Canadian Nuclear Society in Toronto.

As for the previous year the Society joined with the Canadian Nuclear Association to form a joint Honours and Awards Committee. The Committee solicited nominations early in the year and then went through the challenging task of deciding on the recipients. During the event 14 awards were presented to individuals and teams who had contributed significantly to the advancement of nuclear science and technology in Canada.

Ron Mitchel (L) holds the W.B. Lewis Medal presented by Allan Kupcis.

Ed Price, chair of the CNS/CNA Honours and Awards Committee, read out the citations while Alan Kupcis, chairman of the CNA and Ian Wilson, immediate past-president of the CNS presented the certificates.

Following is a listing of the awards, the recipient(s), and the citation supporting the particular award.

W. B. Lewis Medal

The W. B. Lewis Medal is the most prestigious award of the Canadian nuclear community for scientific contribution. It is given to recognize a Canadian scientist or engineer who has demonstrated a level of technical competence and accomplishment in the field of nuclear science and engineering as exemplified by the late Dr. W.B. Lewis during his involvement in the Canadian nuclear energy program, 1946 to 1973.

The W. B. Lewis Medal went to **Dr. Ronald E. Mitchel**

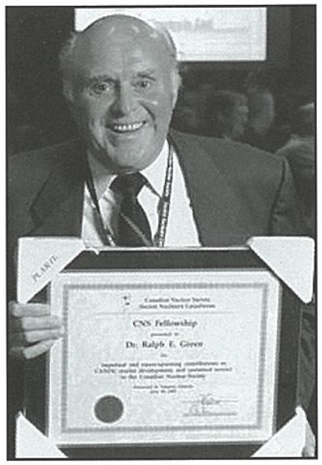
Citation:

Ron Mitchel is recognized worldwide as an outstanding expert on health effects of low doses of ionizing radiation. Dr. Mitchel was educated at the University of British Columbia where he received bachelor, master's and doctoral degrees in chemistry and biochemistry. His research over a 33-year career in radiation biology at AECL has had a major impact on the understanding of low-dose effects. Dr. Mitchel has produced more than 100 scientific publications demonstrating that low doses induce protective responses in cells and whole organisms to resist cancer-causing agents, reduce cancer frequency, increase lifespan, induce DNA repair and cause pre-cancerous cells to disappear - all important health benefits.

His experimental work bears directly on the need to address public concerns and perceptions about health risks and benefits of radiation. A major achievement

Allan Kupcis (R) presents the Ian McRae Award of Merit to Paul Koenderman.

was his successful leadership in the establishment of the unique Biological Research Facility, which has attracted worldwide attention, and has brought in international funding to support the research being carried out. Dr. Mitchel has a remarkable ability to effectively communicate the biological effects of radiation. As a result, he has received numerous invitations to speak internationally. His research has provided convincing evidence that challenges the underlying assumptions of radiation-protection practices. Ron Mitchel's extensive body of work on radiation effects earns him this distinguished award.


Ralph Green

Ian McRae Award of Merit

The Ian McRae Award of Merit is named after the first president of the Canadian Nuclear Association. Its purpose is to honour an individual for outstanding contributions, other than scientific, to nuclear energy in Canada.

The Ian McRae Award of Merit went to **Paul Koenderman**

Citation:

Mr. Koenderman, a graduate of the University of Waterloo and Northeastern University, has spent his entire career at Babcock and Wilcox, moving through engineering and executive positions to become President of B&W Canada from 1987 to 1991 and from 1996 to his retirement in 2002. In the mid-1980s, Mr. Koenderman capitalized on B&W's CANDU steam-generator experience and the parent company's PWR steam-generator designs, and led efforts at B&W Canada to enter the international steam-generator market. B&W Canada was successful in bidding for the supply of North American PWR replacement steam generators and became a world leader in this field. B&W Canada also maintained its role as a major CANDU supplier for projects in Korea, China and Romania.


Hong Huynh

With his personal good humour, intelligence, knowledge and consideration for others, Paul Koenderman has been an able participant in industry and community organizations. He was Chairman of the Canadian Nuclear Association in 1990-1991 and oversaw the development of the CNA into a stronger and more effective organization. He was chairman of the Canadian Exporters Association from 1988 to 1990. He has participated visibly and actively in community organizations, including an appointment to the board of governors of the University of Waterloo. Mr. Koenderman was instrumental in creating a new materials-technology company, Integran Technologies Inc., to exploit the potential of nanocrystalline metals and grain-boundary engineering to provide increased reliability of nuclear-plant components. Paul Koenderman's work in building industrial nuclear manufacturing expertise has been an important benefit to Canada.

Fellows of the Canadian Nuclear Society

The designation of "Fellow of the Canadian Nuclear Society" is given to select members of the Society in recognition of outstanding merit and contribution to the Canadian nuclear program and the Society. Two members were named.

Dr. Ralph E. Green

Ralph Green obtained a B.Sc. in physics from Dalhousie University and a Ph.D. in nuclear physics from McGill University. He joined AECL at the Chalk River Nuclear Laboratories in 1956, and until 1967 was involved in reactor-physics research (using the ZEEP and ZED-2 reactors) which provided data fundamental to the development of CANDU reactors. During his career, Ralph held a wide variety of research, managerial, and executive positions, e.g., as Head of the Reactor Control Branch at Chalk River, as Vice-President and General Manager of the Whiteshell Nuclear Research Establishment (1982-1986), and then as Vice-President, Reactor Development Program. After retiring in 1991, he contributed to the 1997 book on the history of AECL, "Canada Enters the Nuclear Age", by writing the chapter "Safety Research and Development".

Ralph Green is a charter member of the Canadian Nuclear Society, having joined in 1980. He was instrumental in creating the first Simulation Symposium in 1974, and later in having the CNS inherit the continued organization of the Simulation Symposia. He strongly supported the involvement of AECL staff in CNS activities, including the annual conference. Since his retirement, Ralph has been active in the Ottawa Branch, where he has served as judge for CNS prizes at science fairs, and as Branch Secretary since 2000.

M. Hong Huynh

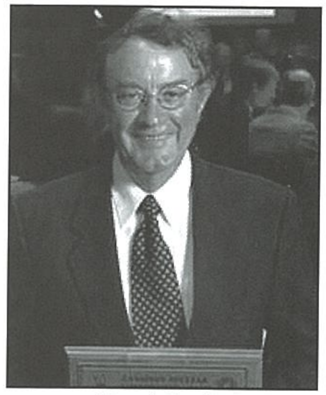
Hong Huynh obtained a B.A. Sc. in chemical engineering from Ecole Polytechnique and a Master's from McMaster University. He joined Hydro-Quebec in 1980, where he quickly displayed leadership in the thermalhydraulics and safety area. He was responsible for the development of SOPHT-G2, a transient thermalhydraulics code. He made significant contributions in a large number of important analyses for the Gentilly-2 reactor, e.g., for ensuring the effectiveness of fuel cooling under accident conditions, and was instrumental in resolving several AECB action items. Hong spent two years (1999-2001) with AECL as its Technical Director in China, where one of his main tasks was the development and implementation of marketing strategies.

In 2001, Hong returned to Hydro-Quebec, where he is presently Head of the G-2 Analysis Section. Hong has played a very active role in the Canadian Nuclear Society: as Quebec Branch Chair for several years, on the executive of the Nuclear Science and Engineering Division, in organizing a number of very successful conferences, and on the CNS Council, where he served in many capacities and eventually as the CNS' 16th President, in 1996-1997. By his enthusiastic efforts, Hong has played an important role in the continuing success of the CNS.

Outstanding Contribution Award

This award recognizes Canadian-based individuals, organizations or parts of organizations that have made significant contributions in the nuclear field, either technical or non-technical. There are two categories of the award, one for individuals and another for organizations or parts of organizations. There were four recipients this year, all individuals.

Ken Petrunik



René Godin

Syd Aldridge

Over the past 25 years, Syd Aldridge has been a driving force at Nutech Precision Metals (initially located in Connecticut), the firm that has manufactured all the pressure tubes in operating CANDU reactors. Since becoming President and CEO, he has ensured that his company continually met the challenge of producing pressure tubes and other reactor-core components to the strict quality standards appropriate to their demanding service conditions.

Syd Aldridge was instrumental in establishing a Nutech extrusion facility in Arnprior, Ontario. This facility enabled Canadian manufacture of pressure tubes for the China Qinshan project and subsequent projects. This avoided the difficulty imposed by the embargo against the sale of U.S.-sourced nuclear products to China. This was achieved by purchasing and installing an extrusion press from Germany that was operational within seven months, while at the same time qualifying a Russian supplier for source material. This facility has since continued as a commercially viable enterprise, extruding and fabricating technically demanding products including other CANDU core components. In addition to his management role, Syd has taken a direct "hands-on" role in the technical aspects of the work, frequently contributing to the optimization of component design. He has provided knowledge and experience in the plant trials of product development programs. In particular, Syd's contribution to pressure-tube technology has been essential to the recent success of the CANDU export program. *(Syd Aldridge was unable to be present at the ceremony.)*

Allan Kupcis (R) presents an Outstanding Contribution Award to Frank Stern.

Dr. Kenneth J. Petrunik

Ken Petrunik graduated in chemical engineering at the University of Windsor. Following jobs at Ontario Hydro, Imperial Oil and Gulf Oil, he joined AECL in 1974 and worked in design, design management, construction management, business planning, and marketing. Ken served as AECL's senior manager in offshore CANDU projects in Argentina, Romania, Korea and China, becoming Vice President for Off-Shore Projects in 1990. In this position he provided outstanding leadership to overcome difficult challenges and achieve successful project completion. He is currently Vice President of the Projects Business Unit.

Ken has an impressive track record in setting up projects and bringing them to a successful conclusion. He does this by careful planning and building effective working relationships with key partners and contractors, both Canadian and international. The selection of project staff and the creation of a strong, capable and effective project team is one of his strengths. The exceptional success of the Qinshan Team in completing its project ahead of schedule and under budget is largely due to Ken Petrunik's leadership. Ken has continually ensured the effective performance of AECL and enhanced the international reputation of CANDU.

René Godin

René Godin has spent the majority of his 40-year career on the design, construction and commissioning of nuclear and related facilities in Canada and abroad. In his retirement, he continues to support Canadian nuclear technology through presentations to professional organizations.

René graduated from the University of Saskatchewan in mechanical engineering, and began his career in the chemical industry. He joined SNC in 1966, and was appointed Resident Mechanical Engineer, and subsequently Chief Resident Engineer, at Gentilly-1 during its construction, and then Chief Resident Engineer at the Glace Bay Heavy Water Plant. In 1974 he joined Canatom and was appointed Site Resident Manager at AECL's La Prade Heavy Water Plant. In 1979, he moved to Korea as Construction Superintendent for Wolsong-1, and became Construction Manager in 1981. His next task, in the mid-1980s, was as Resident Director for the Cernavoda Project in Romania. In 1987, Rene joined the SNC Head Office as Corporate V.P. of Construction, Project Controls and Estimating. During the next ten years he moved through various senior-level executive appointments with SNC Lavalin, and was President and CEO of Canatom NPM Inc. when he retired in 2000. Rene is receiving this award for his important and varied contribution to the Canadian nuclear industry.

Frank Stern

For over 45 years, Frank Stern has been an outstanding provider of innovative thermalhydraulic R&D services. He graduated in mechanical engineering at the University of London and emigrated to Canada in 1952. Frank joined Canadian Westinghouse in Hamilton, transferred to the newly formed Atomic Power Division and was attached to Chalk River Laboratories when many of the basic concepts for CANDU reactors were being formulated.

He returned to Hamilton in 1959 and secured contracts that led to the establishment of the System Test Laboratory in 1962. With AECL support, he added a new facility that included a loop to perform critical-heat-flux testing of CANDU fuel. Frank expanded the business, taking on a large variety of thermalhydraulic projects for domestic and international customers. His team members became experts in conducting complex experiments in support of safety analyses, responding rapidly and efficiently on request.

In 1988, Frank and other employees purchased the facility from Westinghouse and established Stern Laboratories as a private employee-owned company. He has been a mentor to many engineers who were first introduced to nuclear power through their employment in his company. The business has continued to expand in volume and scope, and Stern Laboratories serves a worldwide base of customers, with Frank remaining very active in the company's operations.

Ian Wilson presents the J.S. Hewitt Team Achievement Award to Janet Lossel Sitar and Richard Moffett representing the AECL Hydrogen Recombiner Development Team.

Glen Archinoff and Jim Rippon hold the J.S. Hewitt Team Achievement Award which they accepted for the Bruce A Restart Safety Analysis Team.

J. S. Hewitt Team Achievement Award

The John S. Hewitt Team Achievement Award was established by the CNS in 1994. This awards aims at recognizing the recipients for "outstanding team achievements in the introduction or implementation of new concepts or the attainment of difficult goals in the nuclear field in Canada". Two awards were granted.

Bruce A Restart Safety Analysis Team

The Bruce A Restart Safety Analysis Team has made a crucial contribution to the success of Bruce Power in receiving a licence for the restart of Bruce A Units 3 and 4. The team consisted of staff from Bruce Power and from the AECL-NNC Safety Analysis Consortium, comprised of AECL, NNC, Candesco Research, and Atlantic Nuclear Services. In 2001, this consortium was awarded the contract to perform the safety analysis for the Bruce A restart.

From 2001 July, the start of the project, to 2003 February, a very large scope of work in safety analysis was performed, such as analyses of large-loss-of-coolant events, in-core breaks, low-power conditioning, loss of flow, neutron overpower protection, effect of higher void reactivity, boiler-tube leaks, etc. The analyses, reported in 180 documents, were done to rigorous quality-assurance standards, and resulted in a compelling safety case. The team's tremendous effort was rewarded by the granting of a CNSC operating licence for Bruce A Units 3 and 4 on April 4, only 20 months after initiation of the project. This remarkable achievement, made possible by focused collaborative teamwork among many industry partners, has earned the J.S. Hewitt Team Achievement Award for the Bruce A Restart Safety Analysis Team.

Glen Archinoff and Jim Rippon received the award on behalf of the team.

AECL's Hydrogen Recombiner Development Team

In the unlikely event of a serious accident in a nuclear reactor, hydrogen can be generated from reactions between water and hot components, and from water radiolysis. If not controlled, this hydrogen can threaten containment systems. Staff at AECL have developed a passive device that recombines hydrogen and oxygen in a controlled fashion: the AECL Recombiner. This device represents a novel application of catalyst technology originally developed for use in heavy-water manufacturing processes.

Bringing the device to fruition required the concerted efforts of a multidisciplinary team. Specialists were challenged to find a catalyst that would be active over the desired ranges of temperature and other environmental conditions, and to develop a portable tester to demonstrate its continued performance in-service. Experts in hydrogen behaviour (and in the associated experiments) provided guidance to the product development. Performance was demonstrated under representative conditions. Input from experts in containment engineering, project management, mechanical design, and overall management ensured that the recombiner was engineered to appropriate specifications.

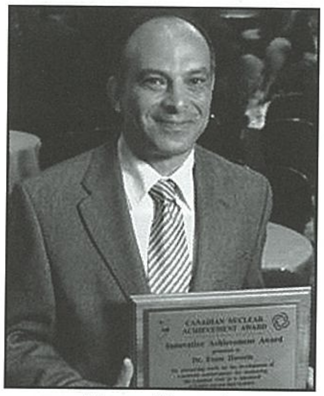
The success of the AECL Recombiner has been demonstrated through its recognition as a technologically significant new product with an R&D 100 Award, and through commercial success with orders from Fortum in Finland and a partnership with Alstom to supply recombiners to Electricité de France.

Janet Loessel Sitar and Richard Moffett received the award on behalf of the team.

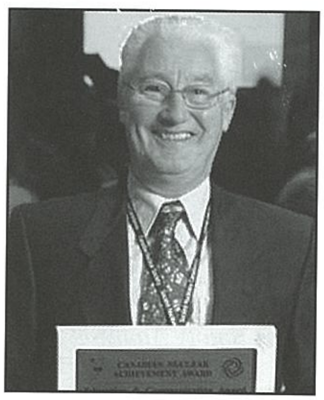
Innovative Achievement Award

The Innovative Achievement Award was established by the CNS in 1991. Recipients of the award are specially recognized for "significant innovative achievement or the implementation of new concepts, which display clear qualities of creativity, ingenuity and/or elegance, and embody an outstanding contribution in the nuclear field in Canada". Two winners of this award were named.

Doug Beattie



Esam Hussein



Clive Greenstock

Doug Beattie

Doug Beattie was the lead engineer in the conceptualization, design, and successful implementation of the innovative mining method in use at the McArthur River uranium mine in northern Saskatchewan. The ore bodies, located at a depth of 500 to 620 m below the surface, have a very high uranium concentration of above 20%, approximately 200 times that of the Elliot Lake mines. The health hazard associated with mining high-grade ore required the development of a remote method. This was further complicated by the porosity of the surrounding fractured sandstone rock, which is subject to groundwater flow. The chosen solution was to freeze the ground in the area of the ore to be mined, develop tunnels above and below the ore body, and then remove the ore by a remote raise-boring technique. The two techniques, freezing and raise-boring, had been used previously for other purposes, but had never before been used in combination for production mining.

Doug Beattie graduated in mining engineering at Queen's University. After working as a mining engineer in Saskatchewan and Australia, he joined Cameco Corporation in 1993 as Senior Mining Engineer at the McArthur River exploration project. He later became Engineering Superintendent during the construction phase, and Mine Superintendent during the ramp-up to full production. He is currently the Corporate Chief Mine Engineer at Cameco's Head Office. Doug Beattie is receiving this award for his leadership in the conceptualization and implementation of this new mining method.

Dr. Esam Hussein

Professor Esam Hussein is awarded the Innovative Achievement Award for his pioneering work on the neutron scatterometer developed for measuring transient void in a heated CANDU fuel channel.

A direct measurement of voiding rate in a CANDU representative channel is very important for addressing a regulatory issue related to behaviour under loss-of-coolant-accident conditions. However, the measurement is exceedingly difficult: conventional means such as gamma attenuation in the fluid does not give sufficient resolution, and secondly, the transient is very short (about 1 s). An accurate, fast-response instrument had eluded the CANDU industry for over a decade. Dr. Hussein conceived and pursued the idea of using neutron scattering, and despite numerous difficulties and setbacks, moved the idea from the concept to bench-scale demonstration stage. This was subsequently developed into a full-scale device by AECL and used successfully in the RD-14M facility.

Dr. Esam Hussein is a professor of Mechanical Engineering and Co-ordinator of the Laboratory for Threat-Material Detection at the University of New Brunswick (UNB). He has Ph.D. in nuclear engineering from McMaster University and received his M.Sc.E and B.Sc.E in nuclear engineering from the University of Alexandria. Prior to joining UNB, Dr. Hussein worked as a nuclear design engineer at Ontario Hydro. He is also an active member of the Canadian Nuclear Society.

The Education and Communication Award

The Education/Communication Award was established by the Canadian Nuclear Society in 1997. This award recognizes the recipients for *"significant efforts in* improving *the understanding of nuclear science and technology among educators, students and the public".*

Dr. Clive Greenstock

Clive Greenstock has a M.Sc. in medical physics and a Ph.D. in radiation physics and chemistry. As a medical and health physicist, he has used his expertise to communicate technically challenging and often misunderstood topics to students, educators, new nuclear employees, and the general public for almost three decades. As a member of AECL's Speakers' Bureau, Clive visited over 300 schools in most Canadian provinces, and about 50 service clubs and societies. At science-education conferences and other venues, he has spoken on the interaction of science and technology with the environment. He has been involved with many aspects of public education and outreach on behalf of the nuclear industry.

Clive Greenstock has been an ongoing volunteer judge at science fairs in Manitoba and Ontario since 1975, including serving as Chief Judge for the Renfrew County Regional Science Fair since 1988. In conjunction with AECL Public Affairs, Clive has helped prepare brochures, displays, videos, and other educational material, and he has participated in several science-teacher seminars, summer-student seminars, and workshops for journalism students. Clive Greenstock has dedicated a significant part of his life to addressing the ongoing need for effective and pervasive public communication on nuclear issues, and has promoted science to educators and students alike.

Bob Jervis presents the award named after him to Sarah Attia.

Student Conference winners Amy Lloyd and Marc Desormeaux.

R. E. Jervis Award

This Award recognizes excellence in research and development carried out by a full time graduate student in nuclear engineering or related fields described below. The Award was established in 1992 by former students of Professor Robert E. Jervis of the University of Toronto, and the CNS to honour his achievements. In the past the Award was administered by the University of Toronto but is now sponsored and administered by the Canadian Nuclear Society.

Sarah Attia

Miss Sarah Attia is awarded the R.E.Jervis Award for her research into the mechanisms involved in the radiolytic formation of organic iodides following a hypothetical loss of coolant accident in a nuclear reactor. The iodides that would be released into the containment, with the coolant, would react with the organic compounds leached from paints by the coolant to form organic iodides.

Sarah's work involved computer modelling to simulate the reaction process. Her analysis was based on results from experiments she performed using a Co-60 gammacell to simulate the reaction, followed by gas chromatography and mass spectroscopy to analyse the organic iodides formed. Sarah Attia is a graduate student at the University of Toronto, and is supervised by Dr Greg Evans in the Department of Chemical Engineering and Applied Science.

Honours and Awards Committee

The members of the 2003 CNS/CNA Honours and awards Committee were:

Ed Price (chair); Allan Kupcis (CNA chairman); Hugues Bonin; Jerry Cuttler; Greg Evans; Colin Hunt; David Jackson; Ben Rouben; Ken Smith; Paul Thompson; Jeremy Whitlock; Walter Thompson, with Denise Rouben providing logistical support.

Student Conference winners

Since the Student Conference did not end until the last afternoon the winners were not acknowledged at the banquet. The winners, as determined shortly after the end of the last session, were: Undergraduate: **Olivier Carrière**; Masters: **Marc Desormeaux**; Doctorate: **Amy Lloyd**. The student papers were judged by a committee headed by the organizer of the Student Conference, **Hugues Bonin**

We thank Atomic Energy of Canada Limited for providing the photographs used above, which were taken by Michael Cooper.

Nuclear Power in the USA

Following are excerpts from the talk by Larry Foulke, president of the American Nuclear society, following his presentation of an ANS Nuclear Histroic Landmark Award for NPD at the luncheon June 9, 2003 of the 24th CNS Annual Conference.

Good News

Larry Foulke

The current performance of nuclear power plants in the US is excellent. Over the past 20 years the average capacity factor has increased from about 60% to over 90%. This increased capacity translates into an additional 23,000 megawatts, the equivalent of 23 plants.

Nuclear electricity production broke another record in 2002 and the safety has been excellent with a reduction in significant safety related events by a factor of 30 over the last 12 years. There have also been substantial reductions in operating and maintenance costs. The production (operation, fuel, maintenance) costs of producing electric power is less than two cents a kilowatt-hour for the average plant and the best plants generate electricity for only about one cent a kilowatt-hour. At the same time there have been substantial reductions in worker exposures to radiation, and quantities of radioactive waste. Most importantly, since the mid-1970s, nuclear energy has enabled the United States to avoid emitting 80 million tons of sulphur dioxide and about 40 tons of nitrogen oxides.

In general, the nuclear industry in the U.S. is in good shape. Performance is excellent and there is a good market for pre-owned plants. Manpower issues are being addressed and university data shows an upswing in enrolments. This is attributable in no small way to President's Bush's National Energy policy, which endorses nuclear power. Yucca Mountain is moving towards becoming a geological repository and the NRC has promulgated a modern licensing process including an early site approval process and pre-certification of reactor designs.

Abundant Energy

The well being of the United States depends on nuclear technology and reliable and abundant nuclear energy. Energy is the daily bread of civilization. We use energy to till the soil, to grind grain, to move lour to the bakeries, and to bake the bread. Energy drives our economy. Our civilization would simply vanish without energy. Energy frees man to be creative.

There is a strong relationship between human development and energy use per capita. It shows that electrical consumption first increases human well being, then people who are well off increase their electric consumption to improve quality of life. However, 1.6 billion people in the world today have no access to electricity (Priddle, 2002). In the year 2000, 1.1 billion people lacked access to safe drinking water (United Nations, 2002).

However.

We have logical and compelling reasons to build new nuclear capacity in the United States. However, despite excellent performance, despite an energy source with so many benefits, despite the benefits of abundant energy, no nuclear plants have been ordered in the United States in the last 25 years. Why?

There have been reasons: over capacity in some regions of the country, low natural gas prices, and public concerns about terrorism, security, proliferation, safety, waste issues. These barriers have not vanished but they have been reduced.

But, today, the greatest barrier is the financing of the first next new nuclear plant. And I'm pleased to share with you today the fact that this barrier is being addressed and, hopefully, being reduced as well.

Draft Energy Legislation

A draft of comprehensive energy legislation is being introduced in the U. S. Senate to reduce that financial barrier. Last month, the Senate Energy and Natural Resources Committee began a series of mark-ups of legislation proposed by Senator Domenici. The draft bill includes several proposed provisions related to nuclear power.

The bill would:

- provide mitigation against financial barriers for building up to six units (8,400 megawatts) of new nuclear capacity with a limit for each new unit of 50% of eligible project costs or $750 million.
- establish an Advanced Reactor Hydrogen Production Co-Generation project. The project shall include research, development, design, construction and operation of a hydrogen production co-generation system using an advanced reactor

The anti-nuclear segment of our population may claim that these steps indicate that nuclear power can't realistically make a come back without financial assistance, at least not in the near term. However, it is only the first plants that will need financial help. Once the learning curve is over and first time engineering costs have been incurred, new nuclear plants will be economically competitive. Furthermore, energy independence and environmental quality are too important to leave to short-range market forces and to the noises of opponents of nuclear power.

What are the Global Opportunities that promote a New Era of Nuclear Power?

Growth in U. S. Energy Demand

At a growth rate of only 1.8% per year, the U.S. will need the equivalent of 393 base-load plants of the 1,000 Mwe class within 20 years. Even if only 20% of this new capacity is nuclear, we are talking about 80 new nuclear plants in 20 years. Incredible!!

Annual growth over the last 10 years has been 2% per year; so this is modest. It will probably grow more like 2.5% per year because of the growth in electrical demand.

We are, increasingly, using energy in the form of electricity. If you go back to the 1880's no electricity was used. Ever since, the share of "all energy" used in the United States in the form of electricity has grown to 40% and that trend will continue (Huber, 2002). According to Huber, more than 90% of the growth in energy demand since 1980 has been met by electricity. Automobiles will continue to become more electrified, become hybrids over the next 10 years, and then be followed by a transition to electric propulsion or the use of hydrogen as a fuel, or a combination of both.

Availability / Security / Reliability of Fossil Fuel Supplies

We must wean ourselves from foreign oil! From the days of President's Carter and Nixon, the commitment and efforts of the United States to reduce oil imports has been anaemic! Oil imports from Persian Gulf countries to the U.S. have risen from 0.3 million barrels of oil per day (MBD) in 1985 to 2.5 MBD in 2000.

Reducing our dependence on foreign oil may not be a solution to terrorism, but it may help. In fact, oil income may be sponsoring terrorist activities.

Alternative Energy Sources

All energy sources will be needed.

Where feasible and sustainable, solar and wind energy will be delivered as electricity just as will nuclear energy. Solar and wind power have always played a role in meeting the world's energy needs and they always will. But when it comes to electricity, they alone simply can't do the job. Just as it takes more potatoes to feed an army than to feed a family, it takes more energy to run a nation (gigawatt chunks) than to run a household (kilowatt chunks). (Hayden, 2001)

Where feasible and rational, the efficient use of energy should be promoted. Over the past two decades, Americans have indeed learned to use energy more efficiently. The United States uses about 10% more energy today than it did in 1973, yet there are more than 20 million additional homes, 50 million more vehicles, and the gross national product is 50% higher. (NSPE, 2002).

Proliferation

Proliferation is a real concern that requires global vigilance.

We need to trumpet the success of the IAEA. Their inspections have been effective. And they get better every year provided we provide them with the funding they need.

North Korea announces it has nuclear weapons and could make more. Iran is building a plant to enrich uranium and experts say that Saudi Arabia, Turkey, Syria and even postwar Iraq, depending on its new government, could be next. The world is teetering on the brink of a nuclear arms race.

But knowing how to operate a nuclear reactor doesn't mean you can build a bomb. The potential connection between nuclear weapons and nuclear power is troubling but not all gloomy. In the last 15 years more countries have given up nuclear weapons or nuclear weapons programs than have acquired them. Ukraine, Belarus, Kazakhstan gave up thousands of nuclear weapons. South Africa gave up six. Argentina and Brazil gave up programs.

Availability of Skilled Work Force

Most science and engineering professions are suffering from availability of a skilled workforce. I have often said that the workforce issue is turning around in the U.S. Enrolments are coming back to nuclear engineering programs in the United States because of the efforts of ANS, NEI and universities.

People are our most important investment and our most treasured resource. The current inflow of new talent with their knowledge does not equal the outflow of experienced talent and their specialized knowledge. Maintaining and cultivating core competencies in nuclear related areas remains a key concern for the industry and the regulators.

Political Ideology

Decision makers often base their decisions based on their perception of public opinion. But their opinions may be skewed by the media and the greater effectiveness of anti-nuclear groups in organizing their message. My message here, then, is that we scientists and engineers have to get more involved in developing relationships with decision makers.

There is no scientific, ecological, technical or economic justification to shut down nuclear power plants.

However, most legislators are lawyers. They approach problems differently. If a lawyer accepts a case, he or she accepts the conclusions of the client - and then spends the effort to rationalize or defend the conclusion.

But, as engineers and scientists, we have a responsibility to society. We must get engaged. We must develop relationships with individual legislators in our home districts where we vote. If we persist and prevail we will win - because we have the facts and the facts will always win at the end of the day. I just can't say when the end of the day will come.

Public Opinion

We must not let misrepresentations propagate. There is a need for realism. There is a need for balance in portrayal.

- A goal of ANS is to be a credible source of information and when we let hysterical misrepresentations pass unchallenged, we are not meeting that goal.
- The media has little sense of what reality is.
- There are hundreds of chemical plants that could result in over 100,000 fatalities with certain accidents. No accident at a nuclear plant could be so severe.
- Intentional airplane crashes into containment will not cause a release of radioactivity to cause harm to the public. Airplanes are like food cans. Containments are concrete barriers. When cans hit concrete, the cans are crushed.

Bottom Line

Now my bottom line message to this audience. The future of nuclear power is international. International leverage for Generation IV reactors is certainly possible and has been set up by the creation of the Generation IV International Forum. There is room for technological improvement in our profession; there is room for international cooperation - and that is what we are here to do and to celebrate!!

Thank you

Open Top Construction On The Qinshan Project

by K.J. Petrunik, K. Wittmann, A. Khan, R. Ricciuti, A. Ivanov, S. Chen[1]

***Ed. Note:** The following paper was given in the technical sessions of the 24th CNS Annual Conference held in Toronto, June 8 - 11, 2003. In the opening paper of the conference, lead author, Ken Petrunik, emphasized the importance of the open top construction method in achieving the completion of the two CANDU units at Qinshan, China, ahead of schedule and within budget.*

Abstract

The significant schedule reductions achieved on the Qinshan CANDU Project were due in large part to the incorporation of advanced construction technologies in project design and delivery. For the Qinshan Project, a number of key advantages were realized through the use of the "Open Top" construction method. This paper discusses the Qinshan Phase III CANDU Project Open Top implementation method. The Open Top method allowed major equipment to be installed simply, via the use of a Very Heavy Lift (VHL) crane and permitted the use of large-scale modularization. The advantages of Open Top construction, such as simplified access, more flexible project scheduling, improved construction safety and quality, and reduced labour are presented. The large-scale modularization of the Reactor Building Dousing System and the Open Top installation method and advantages relative to traditional CANDU 6 construction practices are also presented. Finally, major improvements for future CANDU plant construction using the Open Top method are discussed.

1. General Overview

Currently there are eleven CANDU 6 reactors operating or under construction worldwide.

The first CANDU 6 reactors went into service in Canada in the early 1980s. The latest two units are located at the Phase III Qinshan site, China. The Qinshan CANDU Project is located approximately 125 km southwest of Shanghai (Figure 1). The Project Contract became effective on February 12, 1997. The main contractual requirement was for Unit 1 Provisional Acceptance on February 12, 2003 (actual January 5, 2003) and for Unit 2, nine month later, on November 12, 2003.

Since this is the first CANDU station in China with the same construction schedule as the Reference Plant,

Figure 1: Site Location of Qinshan CANDU Project

Wolsong 3 (the third CANDU in Korea), AECL needed to ensure that the schedule could be met. A feasibility study confirmed that to achieve this schedule, civil, mechanical, and electrical construction were required to proceed in parallel. The best method in achieve this was to employ the Open Top Construction Method.

2. Conventional Construction of Candu 6 Stations

The traditional construction of CANDU 6 stations consists essentially of the following sequence (Figure 2):

a) Complete concrete containment structure (base slab, perimeter wall, ring beam, lower dome and upper dome) with openings on the perimeter wall for the installation of steam generators and the Calandria;

b) Complete civil concrete and steel structures within Reactor Building and Service Building;

c) Complete piping and equipment installation;

d) Complete electrical and control and instrumentation works.

In the traditional construction approach, the movement of equipment in and out of the Reactor Building required that large temporary openings be left in the containment perimeter wall. Most of the structural steel and support systems are con-

1 All of the authors are with Atomic Energy of Canada Limited.

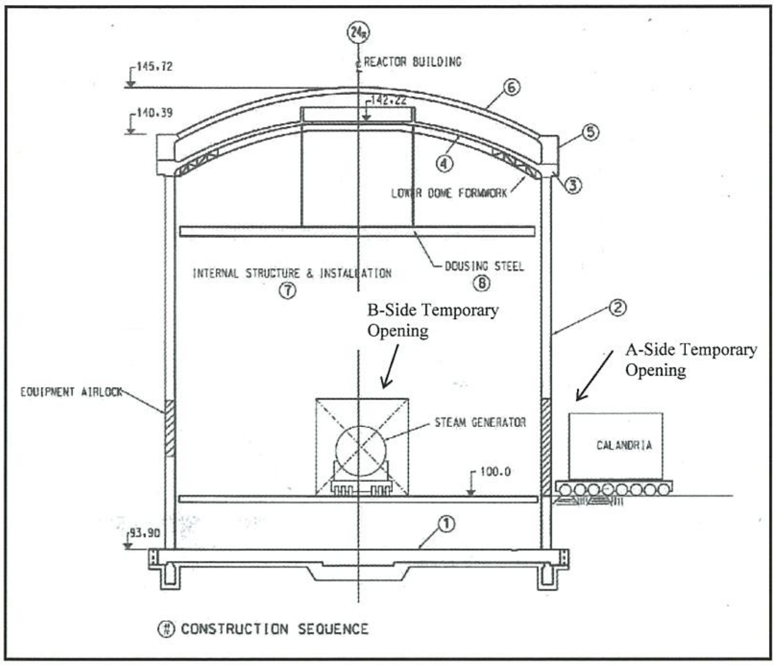


Figure 2: Conventional Construction Method

structed in situ, inside the closed Reactor Building. A result of traditional CANDU 6 construction sequence is that a considerable amount of work takes place within a very confined area with relatively poor access, and in the installation of heavy equipment, horizontal load transfers are needed between different rigging systems, as well as rotation of the heavy equipment. Most importantly, the traditional method does not allow the works of different disciplines to proceed in parallel in the same area and causes delays in the construction process.

High-density construction of the traditional method creates a number of activities requiring special consideration. These activities include managing a large work force inside the Reactor Building, keeping tight control of each phase of construction, transporting large amounts of equipment in and out of the building through the temporary construction openings, and managing multiple trades in a very confined area.

The dousing steel and lower dome formwork are located high at the top of the building. In the traditional method, the work for these structures occurs at the highest elevations of the Reactor Building (Figure 2), resulting in more hazardous worker safety conditions and making normal Quality Control (QC) and Quality Surveillance(QS) activities more.difficult. To achieve acceptable conditions for normal QC and QS activities, extensive scaffolding is required for a long period, which interferes with other construction activities.

3. Open Top Construction Method

Open Top construction eliminates a number of the time-consuming construction activities associated with the traditional CANDU 6 construction method. The Open Top method of construction consists essentially of the following sequence (Figure 3):

a) Complete the containment structure up to the top of the perimeter wall. The perimeter wall (constructed by slip form method) has only one temporary opening for installation of the Calandria. The temporary opening for the steam generator installation is eliminated. The ring beam, lower dome and upper dome are eliminated from the critical path and are constructed in parallel with mechanical and electrical works within the Reactor Building.

b) Install the temporary roof that provides weather protection for the construction activities and equipment in the Reactor Building until the installation of the pre-fabricated lower dome permanent formwork (Figure 4). The temporary roof has hatches with sliding panels for installation of the heavy equipment from the top (Figure 5).

c) Start construction of the concrete structures within Reactor Building and the Service Building.

d) In parallel with b) and c), start piping and electrical works as areas are made available.

e) Start erection of structural steel beginning with the Reactor Building basement and the Service Building division housing the Main Control Room.

f) Install the tubed Calandria on completion of required civil construction through the temporary opening in the perimeter wall.

g) Install heavy equipment (steam generators, moderator, etc) as they arrive at site through the open top (Figure 6).

h) Remove temporary roof.

i) Install heavy equipment at elevation 117 m and D2O Supply Tank and 60-ton crane at elevation 128 m.

j) Install the skew truss as temporary support for the dousing modules. The skew truss spans between the two boiler boxes (Figure 7).

k) Install dousing modules (complete with dousing piping and supports, dousing valves and their platforms, conduits, cable trays, junctions boxes, instrument stands, lighting systems, main steam piping and their bellows, etc.) (Figure 8).

l) Install pre-fabricated lower dome permanent formwork as one piece (Figure 9).

m) Construct ring beam, lower dome and upper dome in parallel with required piping, tubing, electrical and equipment installation.

Table 1 shows the major equipment lifted into the Reactor Building through the open top by a Very Heavy Lift (VHL) crane.

3.1 Benefits of Open Top Method of Construction

A. Schedule

Schedule saving is the most important benefit of the Open

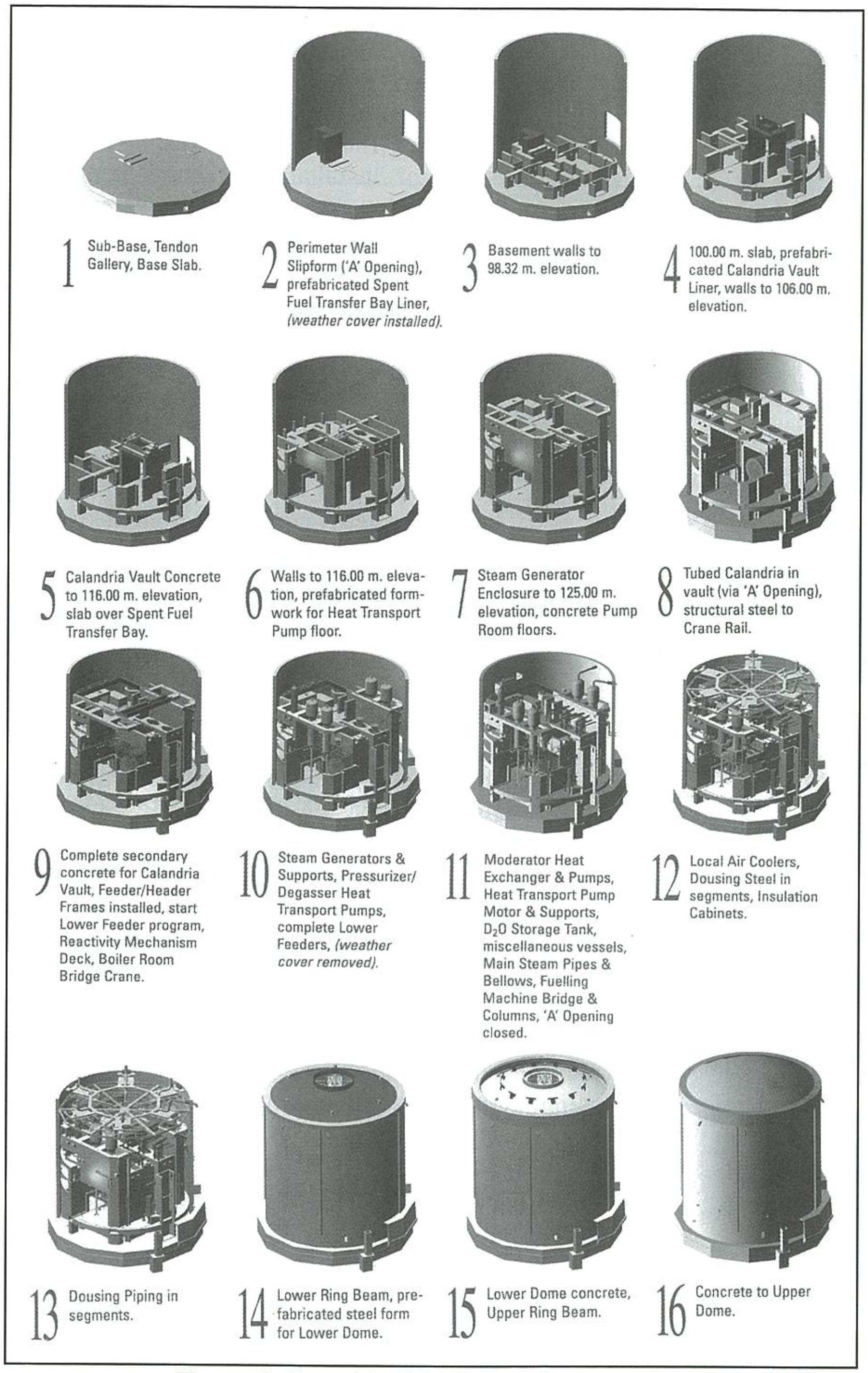


Figure 3: Open Top Method of Construction

Top method of construction. This is realized in main by the following:

- Parallel Working:

  Constructing the ring beam, lower dome and upper dome in parallel with mechanical and electrical installations. This represents a saving of 3 months. Figure 10 shows the assembly works proceeding in parallel for the dousing module and lower dome formwork. This work did not interfere with the construction and installation works taking place inside the Reactor Building.

- Ease and Safety of Installation of Heavy Equipment:

  As an example it takes a maximum of 2 days to install and level one steam generator without any load transfer steps. For traditional construction, a minimum of 2 weeks with difficult load transfer steps in the installation process is required.

- Modularization:

The dousing steel modularization could not have been performed without the Open Top method of construction. This has represented a saving of 3 to 4 months over past practices and produced safer working conditions in the Reactor Building.

B. Improved Construction Quality

The modularization of the dousing steel and the construction of the lower dome permanent formwork at the ground level has resulted in superior quality finished products.

3.2 Construction Flexibility

The Open Top method provided significant construction flexibility and, in some cases, attending schedule benefits. For example, in the traditional construction of CANDU 6 stations, steam generators BO-1 and BO-2 must be installed before steam generators BO-3 and BO-4 respectively. This constraint is eliminated by the Open Top method. On Unit 2, steam generator BO-1 was delayed for 3 weeks due to manufacturing problems, but this did not delay the installation of steam generator BO-3. As the installation of the steam generators is on the critical path in the traditional method of construction, this delay in delivery of BO-1 would have significantly delayed the Project.

Another example is with the installation of the feeders and headers. Traditionally, these could not be installed until after the steam generators because of access restraints. But with Open Top construction, the access constraints are eliminated and the feeders and headers are installed before the steam generators are in place. This installation process on the Qinshan CANDU Project provided further schedule benefits.

4. Key Problems And Resolutions

4.1 Key Problems

The following were the key problems in implementing the Open Top method on the Qinshan CANDU Project

4.1.1 AECL's Risk

Since the Open Top method had not previously been

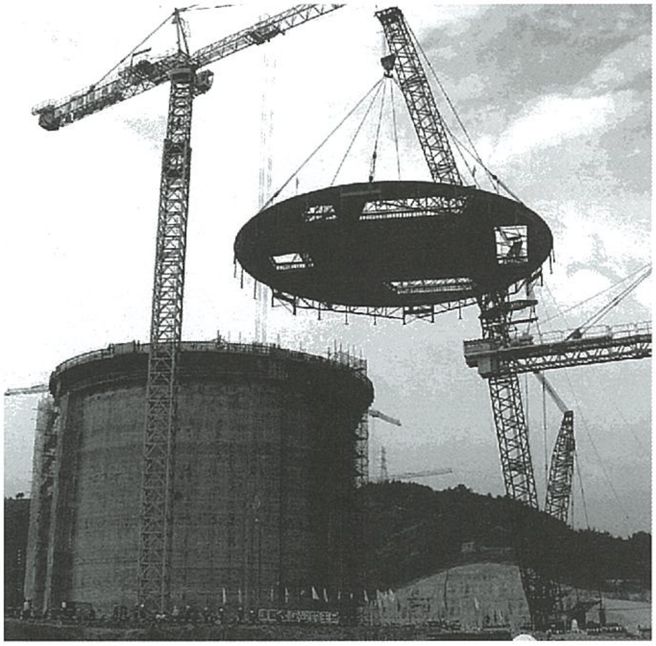


Figure 4: Temporary Roof Installation, R/B11

employed in CANDU construction, it was necessary for AECL to assume increased risks associated with this method including modular and temporary works design, detail work plans, schedule and quality.

Our client TQNPC reviewed our plans and provided effective support in achieving this success.

4.1.2 Site Restrictions

The Qinshan CANDU Project site is located on a very small peninsula (Figure 11). This caused the following challenges:

a) equipment and material logistics
b) space for VHL crane movement
c) space for assembly of dousing modules and lower dome formwork.

4.1.3 Capacity of Heavy Lift Crane

The available VHL crane, a *Liebherr LR 1650*, lacked the capacity to lift 300 tons over a 25-meter reach (lower dome formwork) and 250 tons over a 30-meter reach (steam generator BO-4).

4.1.4 Structural Steel Connection Design and Prefabrication

The following are key items to optimize the Open Top method of construction:

a) temporary roof
b) dousing steel and skew truss modularization
c) permanent lower dome formwork.

These are all structural steel items requiring good experience in the design of steel connections and the preparation

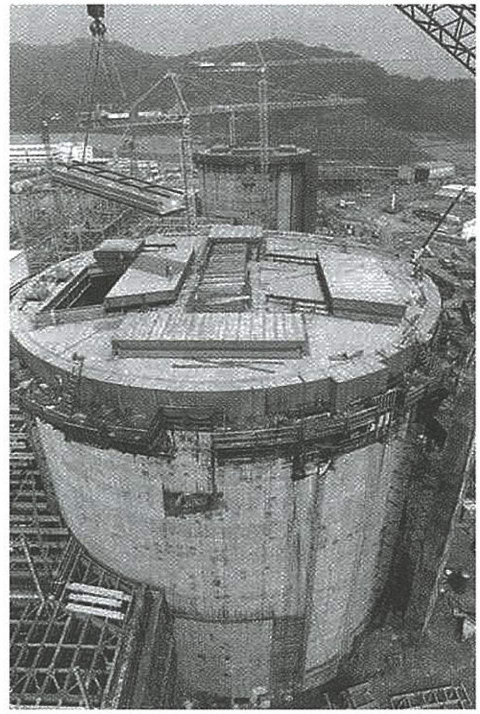


Figure 5: Strategically-placed Openings with Sliding Cover on the Temporary Roof for Heavy Lifting

of erection and shop drawings with special consideration of the lifting and installation sequences. The local contractor did not have this type of expertise and an alternate source needed to be found for connection design of the dousing steel, skew truss and dousing modules.

4.2 Resolution of Key Problems

The following were the major items in the resolution of the key challenges caused by the implementation of the Open Top method on the Qinshan CANDU Project.

4.2.1 Early Decision and Management Support

Senior Project Management made the decision to go with the new Open Top method and gave its full support to a number of important decisions required at the critical times - an essential factor in the success of this construction method at Qinshan site.

4.2.2 Complete Client Support

The Owner gave full support to the proposal. This was a difficult decision, considering it was the first CANDU station in China. To underline the commitment and ensure the success of this method, a heavy lift specialist was provided by the Owner. In addition, the VHL crane was upgraded by the Owner to the required level.

The VHL crane was on site from October 1998 to September 2001 to handle all the heavy lifts required for Units 1 and 2 (more than 70). All lifts were planned in great detail to ensure maximum safety, reliability and efficiency,

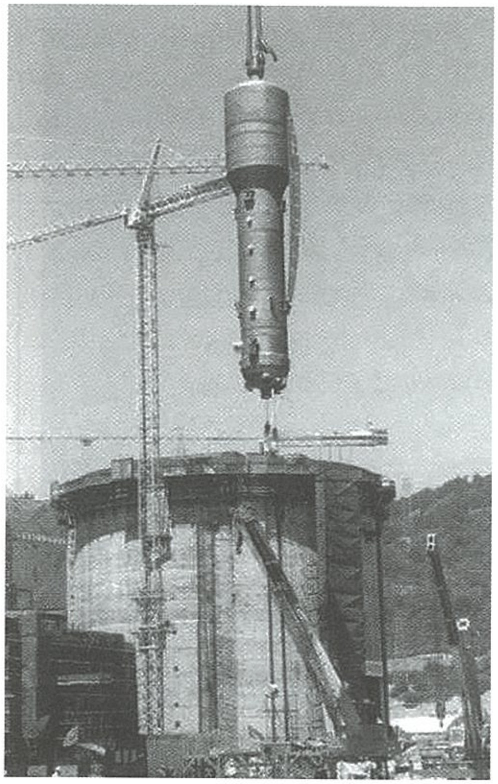


Figure 6: Steam Generator Installation

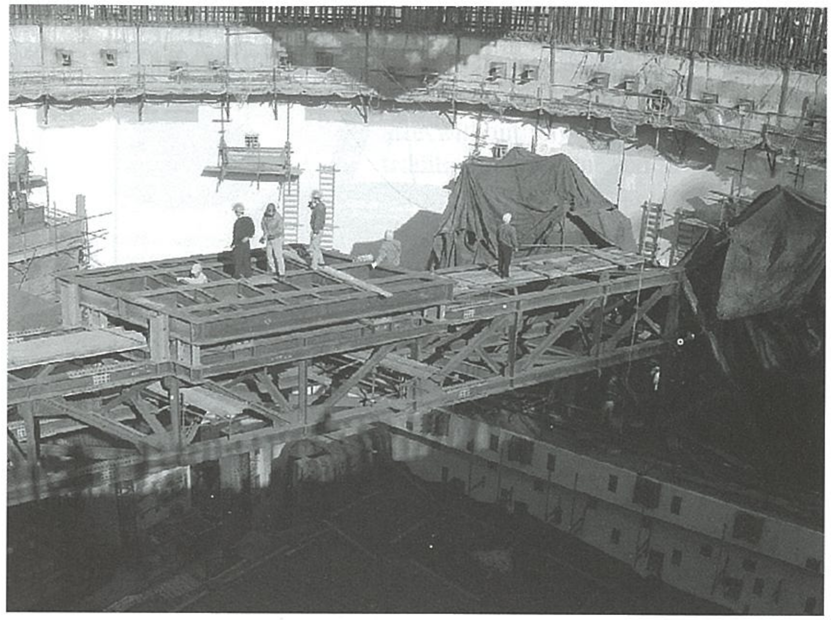


Figure 7: Skew Truss

including fully engineered lifts and use of test weight configurations.

4.2.3 Upgrading of Crane

The Client's crane, a *Leibherr LR-1650*, was brought to the site and upgraded to LR-1800 (Figure 12), through changes of main boom, hook block, control system and suspension counter weight / rod, so that it could perform lifts of:

- 350 tons at a reach of 25 m
- 250 tons at a reach of 30 m.

With the upgrading, the crane was capable to lift the lower dome formwork and steam generators BO-4 on both units with acceptable safety margins.

4.2.4 Provision of Structural Steel Expertise

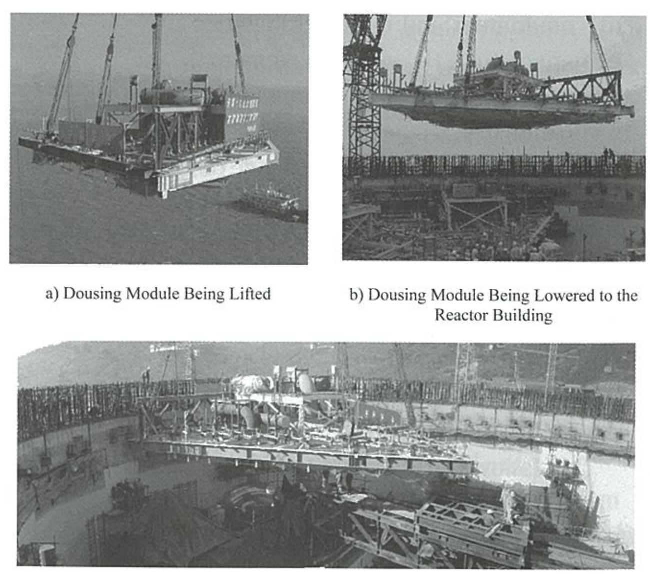
The design of steel connections for the dousing modules and skew truss was assumed by AECL's Site Project Management Organization (SPMO). Project Management took immediate action to bring in additional staff from Canada to assist the main Project staff in the connection design and checking of the shop drawings for the skewed truss, dousing steel and the lower dome permanent formwork.

5. Results And Lessons Learned

The Open Top method of construction was a unique success to the extent that all future CANDU stations will be built using this approach, to further reduce schedule and improve quality. The work was performed according to the plan, with 70 heavy lifts.

6. Conclusion And Future Improvement

Open Top was implemented at the Qinshan site with great success, providing flexibility in construction sequence, reduced schedule durations, streamlining of construction logic, improved construction quality and work safety,



a) Dousing Module Being Lifted

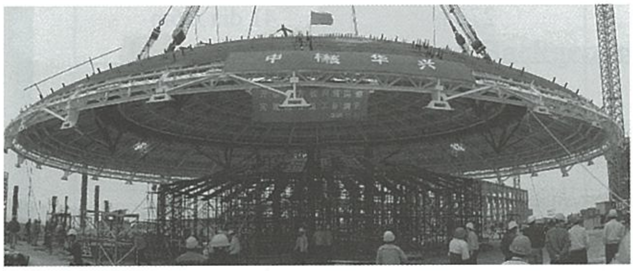
b) Dousing Module Being Lowered to the Reactor Building

c) Modules 5 Is Placed in the R/B (Supported by the Permanent Brackets on the Perimeter Wall and the Temporary Skew Truss at the Centre)

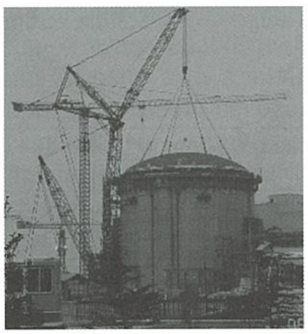
Figure 8: Dousing Steel Module installation

improved Reactor Building access and less construction congestion in work areas.

Adding additional modules in future CANDU projects can expand the Open Top program. This will further reduce congestion of the working area inside the Reactor Building, improve the construction quality and is expected to provide further schedule benefits. Additionally, the Heat Transport System motors should be installed with the VHL crane, thus completing the installation of all major equipment with this crane.



a) Lower Dome Formwork Being Lifted from Assembly Yard



b) Lower Dome Formwork Being Placed in the Reactor Building

Figure 9: Lower Dome Installation

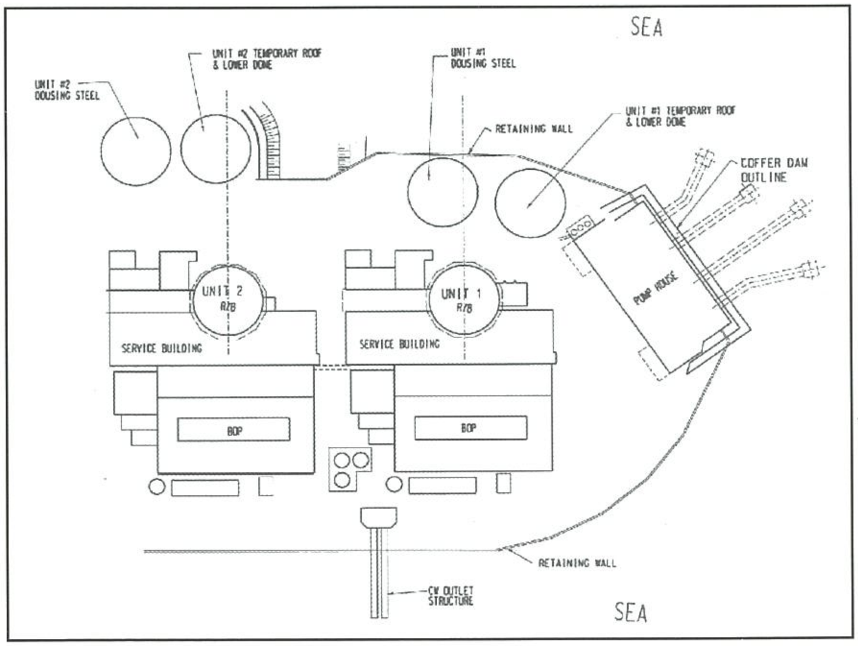


Figure 11: Site Layout

New CANDU designs such as the CANDU ACR are based on using open top and heavy lift as part of the design phase with construction input that is producing major improvements in cost and schedule.

7. Acknowledgment

AECL acknowledges the support of the Third Qinshan Nuclear Power Company (TQNPC), the owner of the Qinshan CANDU Project, and in particular the guidance and experience of Mr. Zhang Gui Bao, TQNPC's Chief Civil Engineer and Mr. Hu Ke Shu, TQNPC's heavy lifting specialist in the successful implementation of the Open Top method of construction. AECL also acknowledges the support of the NSP Contractors, Hua Xing Construction Company and CNI 23 Construction Company and in Canada, Allen, Adjelian and Rubelli and Canatom Inc. throughout the implementation of the Open Top method.

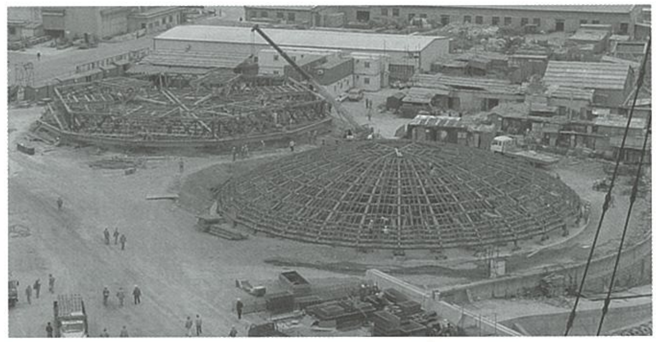


Figure 10: Dousing Steel and Lower Dome Formwork Assembly Area at Site (Unit 2)

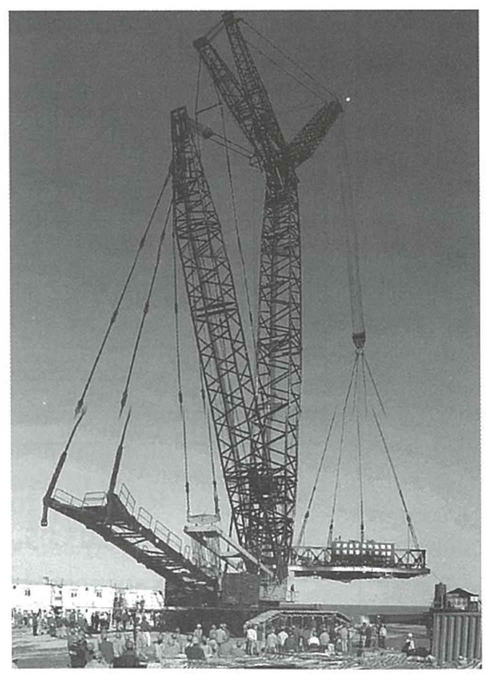


Figure 12: Upgraded VHL Crane LR-1800

Table 1: Major Lifting through the Reactor Building Open Top

Equipment	Date of Lifting	Net Weight	Max. Dimension
R/B 1Temporary Roof *	1998-12-23	181 t	41 dia x5x3.5m
R/B 2Temporary Roof *	1999-04-01	181 t	41 dia x5x3.5m
R/B 1 Dousing Modules	2000-11-22 to 2000-11-28	6 liftings with total 545 t	21radius x7.6m
R/B 2 Dousing Modules	2001- 07-13 to 2001-07-15	6 liftings with total 542 t	21radius x7.6m
R/B1 Lower Dome formwork	2000-12-11	273 t	41 dia x 6m
R/B 2Lower Dome formwork	2001-07-23	273 t	41 dia x 6m
R/B 1 Skewed Truss	2000-11-18	50 t	32x6.5x3m
R/B 2 Skewed Truss	2001-07-11	50 t	32x6.5x3m
R/B 1 Steam Generators	B01:2000-07-14 B03:2000-07-21 B02:2000-08-17 B01:2000-08-22	220t each	5.3 dia x 20m long
R/B 2 Steam Generators	B02:2001-02-23 B04:2001-03-02 B03:2001-05-29 B01:2001-06-23	220t each	5.3 dia x 20m long
R/B 1 PHT Pump P1-P4	2001-08-23 to 2001-09-03	46t each	4.2x4.11x4.37m
R/B 2 PHT Pump P1-P4	2001-12-29 to 2002-12-09	46t each	4.2x4.11x4.37m
R/B1 Feeder header frame	2000-07-02 to 2000-07-03	52t-55	7.29 x 6.61 x2.92m
R/B2 Feeder header frame	2000-12-27 to 2000-12-29	52t-55	7.29 x 6.61 x2.92m
R/B1 Reactivity Mechanism	2000-04-27	43t	6.1x4.6x0.8m
R/B2 Reactivity Mechanism	2000-11-08	43t	6.1x4.6x0.8m
R/B 1 Pressurizer	2000-04-05	110t	16.15x2.13
R/B 2 Pressurizer	2000-09-22	110t	16.15x2.13
R//B1 Degasser condenser	2000-11-16	49t	7.5x2.23m
R//B2 Degasser condenser	2001-07-09	49t	7.5x2.23m
R/B 1 CR-01 Crane	2000-11-02	69t	21x6m
R/B 2 CR-01 Crane	2001-02-06	69t	21x6m
R/B 1 Moderator heat exchanger	2000-10-17	56 t	1.93 x 10.37m
R/B 2 Moderator heat exchanger	2000-11-21	56 t	1.93 x 10.37m
R/B 1 Emergency Core Cooling	TK1/3:2001-02-26, TK2:03-13	104t each	4.2x12.7m
R/B 2 Emergency Core Cooling	2001-09-05/06	104t each	4.2x12.7m
R/B 1 Calandria * *	1999-11-29	450t	8.96x 8.53 x 8.48m
R/B 2 Calandria * *	1999-11-29	450t	8.96x 8.53 x 8.48m

* R/B temp roof removed on 2000.11.12 and R/B2 temp. roof removed on 2001.07.05

** transported through the A-opening

Opportunities For CANDU For The Alberta Oil Sands

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1. Introduction And Background

The Alberta oil sands bitumen deposits comprise of one of the largest sources hydrocarbon in the world, and have emerged as the fastest growing, soon to be dominant, source of crude oil in Canada.

The oil industry has made great strides in improving the effectiveness of gathering this resource. In particular, alternatives to open-pit mining have been developed which enable in-site recovery of underground deposits with a minimum of environmental disruption. The main challenge that remains is the large quantity of energy needed in the process of extracting the oil and upgrading it to commercial levels. For a typical in-situ extraction project, about 18% of the energy content of the oil produced is used up in the extraction process, while a further 5% is used in generating hydrogen to upgrade the bitumen to synthetic crude oil.

Looking ahead, even as improvements in energy use efficiency, (and hydrocarbon use efficiency) counterbalance the increases in hydrocarbon demand from economic growth (particularly in the developing world), Canada and Alberta recognize that the oil sands resource will be needed, and both support the development of this resource in an environmentally responsible way.

The large energy requirement for the oil sands extraction process represents a challenge with regard to both environmental impact and security of supply. The use of natural gas, the current energy supply, has impacts in terms of air quality (via NOX and other emissions) and also represents a large greenhouse gas emissions component. As the oil sands industry expands, the availability of natural gas also becomes a concern, as does price and price stability.

With this background, the opportunity for nuclear reactors to provide an economical, reliable, virtually zero-emission source of energy for the oil sands becomes very important. Over the last few years, developments in oil sands extraction technology, and developments in CANDU technology through the Advanced CANDU Reactor, (ACR .), have converged so that a practical, economical match of nuclear energy to the oil sands is now available.

This paper describes recent studies by AECL and by CERI (the Canadian Energy Research Institute) to look at the adaptation of the ACR design for use in the oil sands, in particular with regard to economic viability. Issues raised in these studies are discussed, along with priorities for further work.

2. Summary Of Oil Sand In-situ Production

2.1 SAGD Facility description

Steam Assisted Gravity Drainage (SAGD) is an enhanced oil recovery process applicable to in situ recovery of crude bitumen from deep oil sands deposits. A typical application involves twin horizontal wells drilled in parallel, with one a few metres above the other. During the start-up phase, medium pressure steam is circulated in both wells to heat the reservoir of bitumen-sand mixture by conduction. The heating reduces the viscosity of the bitumen, increases its mobility, and establishes pressure communication between the two wells along their length, so that a flow of fluids can occur from the upper well to the lower well.

Once communication is established, the lower well is placed on production and the upper well begins injecting steam, representing the start of "normal" SAGD operations. Continued steam injection gradually creates a steam chamber above the well-pair, which expands upwards to the top of the reservoir and laterally until contact is made with similar steam chambers from adjacent well-pairs.

The steam injection rate through the upper well is increased until the desired reservoir operating pressure is achieved, then varied to maintain that pressure. Driven by this pressure and by gravity, liquid bitumen and water flow as a mixture from the upper well to the lower well. The mixture then flows to the surface where it is processed to recover the bitumen and recycle the water through cleanup

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Table 2
Main Parameters, Economic Model

Currency reference:	Constant Canadian dollars, January 2002
Discount rate:	10% (real)
Electricity price (plant gate):	Cdn $50/MWh
Natural gas price (plant gate):	Cdn $4.25/GJ (equivalent to US $3.50/mm btu NYMEX)
Project energy supply:	62,400 m3/day steam
:	150 Mwe (gross)

Table I
ACR Main Design Parameters

Reactor thermal output:	1983 MW (th)
Nominal plant electrical output:	728 Mwe (gross)
Reactor coolant system pressure:	12MPa (at reactor outlet header)
Reactor coolant system inlet temperature:	278.5º C
Reactor coolant system outlet temperature:	325º C
Nominal boiler steam pressure:	6.5MPa (a)
Nominal boiler feedwater temperature:	218º C
Number of fuel channels:	284
Number of fuel bundles per fuel channel:	12
Fuel design:	43-element CANFLEX fuels

plant and closed-cycle boilers. The flow rate from the production well (lower well) is controlled so that the "bottom hole" (in-well) temperature of the produced fluids is several degrees Celsius below the saturation steam temperature at the operating pressure. This prevents steam from breaking through into the production well.

Steam injection continues until the steam/oil ratio (number of cubic metres of steam injected to produce one cubic metre of crude bitumen) reaches a value where it is no longer economic to continue. Over the life of each well-pair, production typically requires an average steam-oil ratio of 2-3. SAGD is capable of recovering well over 50% of the initial volume of crude bitumen in place.

Steam is usually generated at a central plant and then distributed to the injection wells. The central plant also serves as the processing site for produced fluids and gases.

To establish a reference project output for the purpose of this comparison, working from output levels of 62,400 m 3 /d of 100% quality steam (see Table 2), an assumed cumulative steam/oil ratio of 2.5 was applied to derive a hypothetical SAGD project size. Based on an operating capacity of 93%, the result was consistent with a 23,200 m 3 /d (146,000 b/d) bitumen production SAGD operation in northwestern Alberta, targeting a high-quality Athabasca resource.

A project of this size is large relative to existing commercial SAGD projects; however, several companies are proceeding with projects in the 12,700 m 3 /d (80,000 b/d) to 15,900 m 3 /d (100,000 b/d) range and beyond. For example, one of the largest projects, envisages a series of stages of 35,000 bbl/day or 50,000 bbl/day bitumen each, with four to eight stages expected, giving an ultimate potential output of 140,000 to more than, 300,000 bbl/day. (The first stage of this project is expected to start production this year).

3. Summary of ACR-700 Design

The ACR-700 design is an evolutionary development of familiar CANDU technology, adding a carefully chosen set of innovations to the major improvements in economics, operations and safety margins. With a gross electrical output of approximately 728 MWe, the ACR follows the same size range as AECL's standard CANDU 6 design, allowing much of the extensive experience base in CANDU 6 design, construction and operation to be utilized.

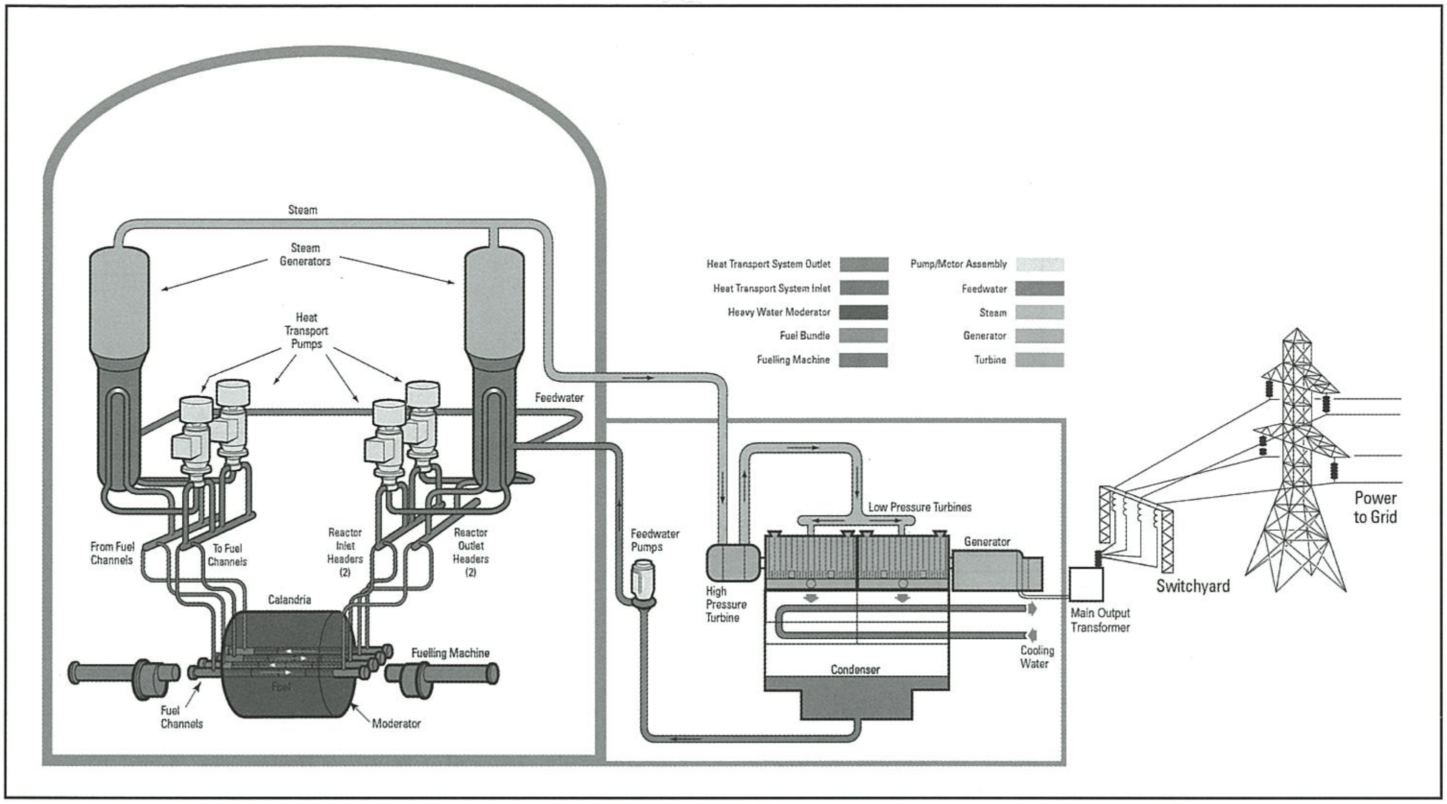
The ACR-700 design is rooted in the proven principles and characteristics of the CANDU system, and uses standard features of CANDU pressure tube technology built up over many decades of operation:

- Modular horizontal fuel channel,
- Available simple, economical fuel bundle design,
- Separate cool, low-pressure heavy water moderator with back-up heat sink capability,
- On-line/at power fuelling,
- Fuel cycle flexibility with high neutron efficiency,
- Passive moderator/shield tank heat sinks surrounding the pressure tube core,
- Two robust, quick acting, passive shutdown systems.

The following key features, derived from the enabling technologies, are incorporated into the design concept of the ACR

- Slightly enriched uranium fuel (nominally 2% U-235), contained in CANFLEX bundles to achieve burn-up (approximately 20 MWd/kgHM) and with further increases as operational experience increases,

Figure 1: Schematic of typical ACR plant



- Light water replacing heavy water as the reactor coolant,
- More compact core design with reduced lattice pitch, reducing heavy water inventory and providing a highly stable core neutron flux,
- Enhanced safety margins, due to optimized power profile and void reactivity,
- Higher coolant system and steam supply pressure and temperature resulting in an improved overall turbine cycle efficiency,
- Reduced emissions, due to radiolysis of heavy water,
- Improved performance through advanced operational and maintenance information systems, and improvements to project engineering, manufacturing and construction technologies.

A simple diagram of the ACR-700 design is shown in *Figure 1,* and main design parameters are given in *Table 1.* A more detailed description of the ACR is given in Reference 1.

4. Assessments of ACR As Energy Supply For Oil Sands Facilities

AECL has carried out recent studies looking at the following topics:

- Adaptation of ACR configuration to steam and electricity cogeneration for oil sands application
- Economic comparisons of ACR energy with the conventional energy option, natural gas
- Review of feasibility issues with siting an ACR in the oil sands producing region

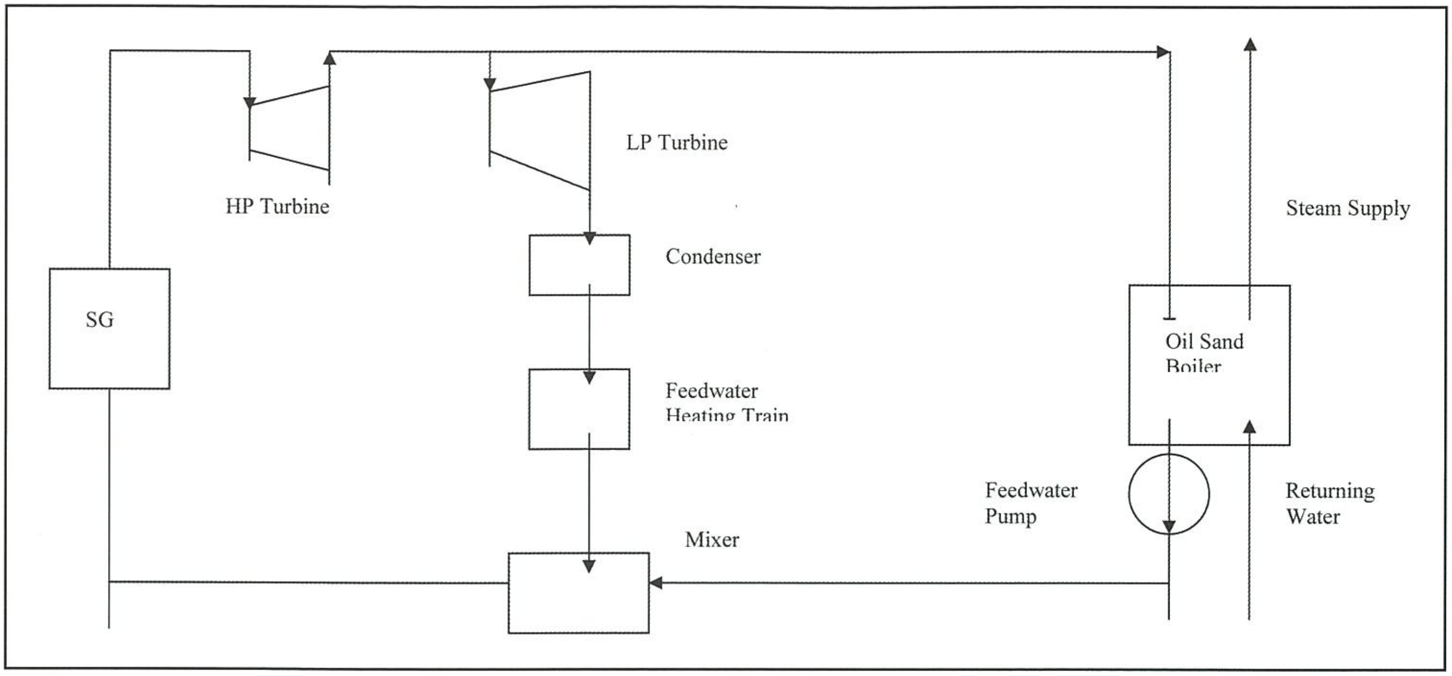
AECL has worked with oil companies, independent experts and with the Canadian Energy Research Institute to understand the requirements of this application and to develop realistic models for economic comparison. CERI's current studies of ACR and natural gas economics form an independent reference point from which further work can be done to optimise ACR applicability for the oil sands.

4.1 Adaptation of ACR Configuration

The fundamental product of a CANDU nuclear power plant is steam, from the reactor coolant system steam generators. Thus, adapting a secondary heat cycle to exchange the energy from this steam, and generate process steam for oil-sands application is, in principle, straightforward. As discussed above, the steam pressure desired as the starting point for delivery to SAGD oil wells, can vary with the circumstances of the oil field, from 2-6 Mpa. In addition to steam supply, SAGD production facilities can be significant consumers of electricity. The rapidly increasing level of industrial activity associated with the oil sands industry is increasing overall regional electricity demand. The result is that cogeneration of steam and electricity is a naturally advantageous configuration to consider for the ACR.

In practice, each large oil-sands project will have its own unique characteristics in terms of: steam supply magnitude and quality; desired steam pressure; geographic location; electricity demand; etc.

Figure 2: Co-gen configuration diagram a)



As a result, for each project, an ACR configuration would be defined which is adapted to meet individual project needs while optimising ACR economics as far as possible.

While working with oil companies at an early stage, to better understand their specific requirements, AECL has defined a range of configurations to take advantage of ACR characteristics and provide suitable oil sands production support.

(a) For lower steam pressures and smaller-scale electricity production, the ACR steam supply (at 6.5MPa) is passed first through a high-pressure turbine, emerging at a suitable pressure (~2.5 – 3.5MPa) to pass through a tertiary boiler, where remaining heat is transferred to SAGD oil-well steam supply at 2-3 MPa. This configuration is shown in Figure 2. For an ACR-700, the typical outputs would be:

- ~140 MWe (net)
- 420,000 bbl/day steam
- steam supply pressure 2.2Mpa

The production rate of bitumen using this steam would depend on the steam-oil ratios required in the SAGD wells. For steam-oil ratios of 212.4-224.0 °C, the bitumen production rates would be 168,000 – 210,000 bbl/day.

This configuration has some advantages in economics, because of the very efficient system configuration, but has more limited flexibility in terms of adjusting steam and electricity outputs.

(b) For high steam pressures and/or a greater degree of electricity production or lower steam delivery, an alternate configuration has been considered (Figure 3). In this case, the steam supply to the turbine and the steam supply to the tertiary, oil sand boiler would be in parallel.

By suitable choice of feed water heating system conditions to match the return feed water conditions to the nuclear side, from the tertiary boiler, the drain temperature is chosen to match the feed water temperature requirements. This configuration can deliver steam at pressures up to 5 or even 6 MPa, and has a great deal of flexibility in adjusting steam versus electricity outputs.

Other ACR configuration adaptations are also being considered. However, economic evaluations so far have been based on these options.

As discussed below, these ACR configurations have been studied at to confirm feasibility from the viewpoint of siting, equipment supply, licensability, and economics. The configurations are based on the use of the standard ACR-700 nuclear steam supply design with no changes; that is, adaptations are restricted to the Balance of Plant configuration. Configurations that adapt the nuclear steam supply of the ACR would also be possible, but would involve a substantial degree of pre-project design engineering, and associated costs.

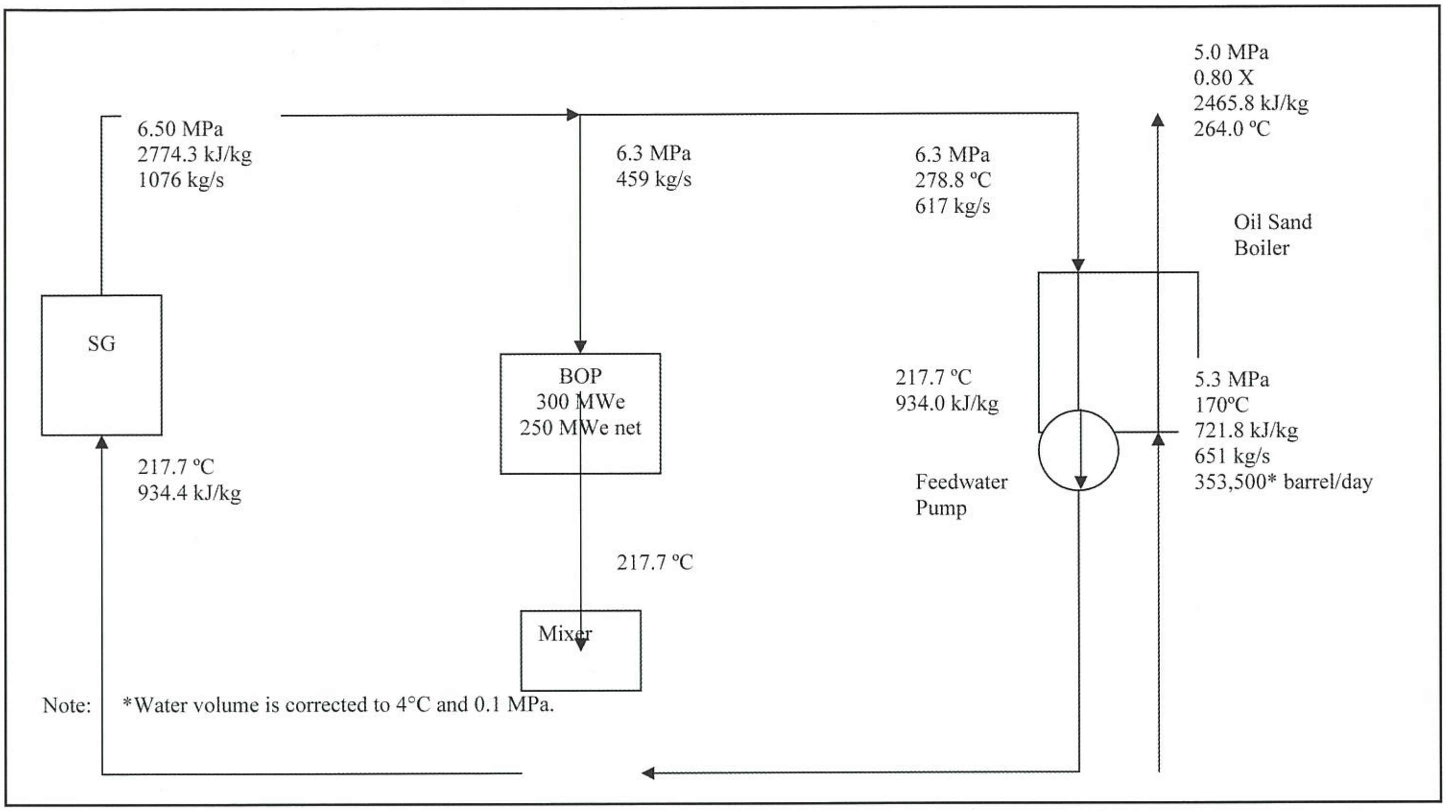
4.2 ACR Economics

4.2.1 Initial Studies

Initial studies of ACR economics were carried out with the configuration (a) above, and with the pre-conceptual design of the ACR. In these studies, the application of an "N'th-unit" repeat-plant ACR was considered, and nuclear economics were compared with natural gas as the alternative.

The studies also considered the economic impact of CO2 emission credits, if these were available to the nuclear option. They also considered the impact of the costs charged for emissions of SO2, NOX, VOC's (volatile organic compounds) among other air pollutants associated with the natural gas option.

Figure 3: Co-gen configuration diagram b)



The main economic assumptions for this initial study were based on energy trends to the year 2000, and included:

- Assumed plant-gate electricity price: $45/MWh
- Assumed natural gas cost at site: $45/GJ
- Assumed total cost of supplying natural-gas steam to the oil sands facility; $4/bbl of bitumen (composed of $3.10/bbl fuel cost and $0.9bbl capital and operating charges)

The reference case for the study was the ACR configuration described in 4.1 (a) above, with a net output of ~140 Mw and steam supply for 210,000 bbl/day of bitumen (assuming a steam and ratio of 2:1).

The study also looked at different target values of return on investment for the capital expenditure target values of return on investment for the capital expenditure for the ACR; - the other most significant economic parameter. The study concluded that, for an "N'th unit" (repeat unit) ACR-700, with a return on investment of 14%, the ACR steam price would be more than 10% cheaper than steam from a natural gas boiler, neglecting any CO2 or pollution credits.

The study also concluded that, for the case where emissions to the Fort McMurray air shed are constrained for SO2, NOX, VOC's, the savings in emission costs for the ACR are:

- $20,000/day for SO2, NOX and VOC's
- $50,000/day for CO2 credits at year 2000 assumption of $7.50/tonne

These savings represented 3.7% and 9% respectively in comparison with the natural gas case.

As noted above, these credits would significantly increase the ACR cost advantage, if applied.

4.2.2 CERI Economics Study

Most recently, AECL commissioned an independent study by CERI (Canadian Energy Research Institute) to compare the economics of ACR-supplied energy with natural gas. This study provides a more up-to-date evaluation using most recent assumptions on configurations and economics and compares identical energy supplies from the nuclear and natural gas options respectively to ensure an apples-to-apples comparison. The study identified comparable ACR and natural gas supplied configurations each delivering both steam and electricity. This enabled the optimum gas configuration cogenerating electricity and steam for a typical large-scale SAGD operation. A common economic model was also developed, using parameters such as gas and electricity costs based on recent norms, but without attempting to extrapolate or forecast future prices. Table 2 gives values of the main parameters.

The results of the study show that, based on a gas price of $4.25 Cdn/GJ (equivalent to $3.25 US/mm btu reference price on the NYMEX commodity exchange), the nuclear option achieves a 10% advantage in steam cost. For comparison, current 2003 gas prices have averaged $5.76 US/Mmbtu so far, and long-term prices are predicted to trend in this direction based on the costs of LNG imports and arctic gas supply. The study also looked at energy price sensitivity to changes in key parameters. The results are shown on *Table 3*.

Economically, the potential for a nuclear advantage is shown in a lower sensitivity to main parameters. A 25% increase in capital cost (the most significant nuclear parameter) would increase steam costs by 20% from $8.61/tonne to $10.30/tonne, while a 25% increase in the price of natural gas would increase steam cost from $9.42/tonne to $11.78/tonne. In practice, the volatility of natural gas prices has been significantly greater than this. The result shows that, in this regard, nuclear has a significant advantage in cost risk.

The study also looked at the impact CO2 of emissions costs on the comparison. The current reference basis for CO2 costs or credits is the value of $15/tonne, stated by the Canadian government as an envelope to short-term CO2 costs in its Kyoto strategy. This CO2 cost would add 18% to the cost of natural gas-supplied steam.

Further work is continuing to better understand the economics of the ACR option in comparison to other fuel alternatives, and to define the costs of different ACR configurations and site-specific costs in more detail. Clearly, though, the ACR is able to offer significant economic potential, along with the elimination of air emissions.

4.3 Project Feasibility

AECL's initial studies confirmed project feasibility at the basic level.

- The ACR can be positioned on the ground at the typical SAGD production sites, meeting civil engineering requirements for foundations, seismic resistance, extreme weather, etc.
- The ACR can be configured based on a high degree of water conservation and recycle, to meet stringent local water use requirements
- As in other CANDU applications, the ACR would comply with all federal and provincial environmental protection requirements and expectations
- The ACR is designed for highly modular equipment and structure assembly, construction and installation. As such, risks and costs due to construction in a remote site can be kept to a minimum by the large fraction of the work done in offsite module fabrication. The ACR is designed to enable road shipment of all modules from Edmonton to the Fort McMurray and other site areas.
- The timing for a first ACR unit on-line, 2011, is consistent with typical timing for the building of proposed SAGD projects to full-scale production.

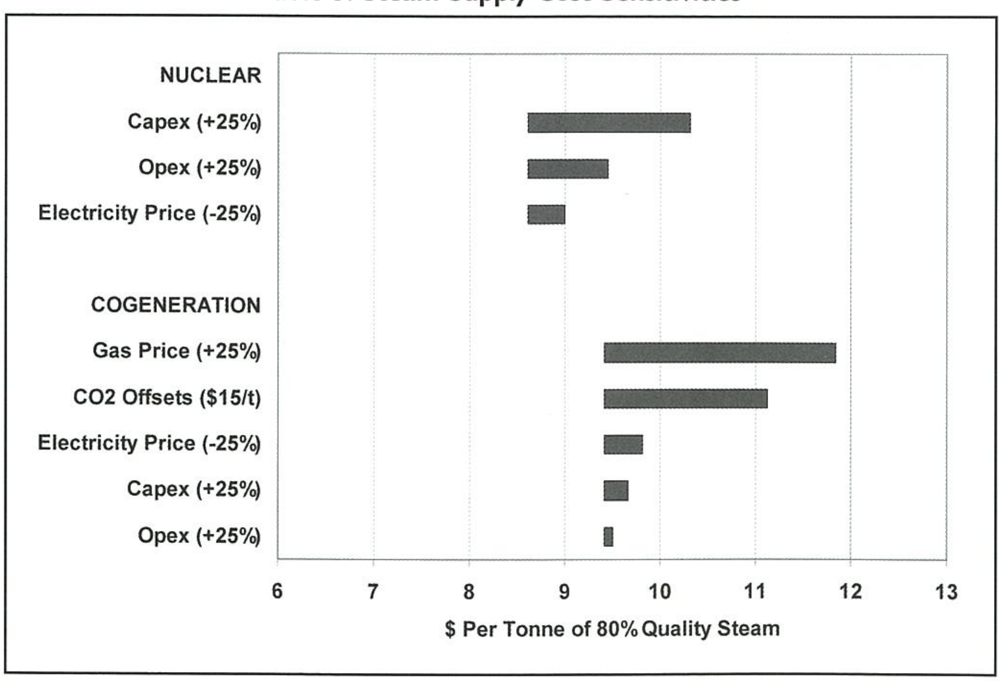
In the more recent evaluation work, the CERI study identified some important considerations affecting this application for the ACR. Further AECL work will study these considerations and identify ways to successfully address each issue:

- **Staged production and risk profile**

SAGD projects have typically been planned in stages, steadily increasing in total capacity as each successive stage comes on stream. This enables oil companies to reduce market risks and distribute decisions on capital outlays over an extended period, with offsetting revenue steadily increasing.

The selection of ACR energy supply involves a large one-time capital commitment. Mitigating this issue is AECL's current track record of on-time, on-budget completion of CANDU 6 power reactor projects in Wolsong, Korea, and Qinshan, China, as well as the fact that the ACR economic competitiveness, shown above, is consistent with the ACR on-stream at the time the project reaches full production, as a replacement for gas-fired capacity.

Table 3: Steam Supply Cost Sensitivities



- **Hydrogen Production**

The reference economic model assumes steam and electricity production at steady prices. A third energy-related requirement for oil-sands production is the need for hydrogen, for upgrading of the bitumen to synthetic crude oil. Since the electricity market in Alberta exhibits lower prices for off-peak electricity, the electrolytic production of hydrogen with off-peak electricity may show economic promise. A further economic benefit would arise via the synergistic production of heavy water, (the ACR moderator synergistic production of heavy water, (the ACR moderator material) as an economical add-on stream to the hydrogen production.

- **Steam Distribution**

Since individual SAGD oil wells would need to be placed at varying distances apart, the economics of a central steam source such as the ACR, will depend on the cost of transporting steam to the individual wells.

For some proposed projects, the individual wells are planned to be arranged around a single central distribution source, with a radius of one or two kilometres, which would be very compatible with the ACR. In other cases, where steam distribution may be over several kilometres, the ACR configuration (e.g. choice of steam pressure) would have to be carefully chosen, to minimize energy losses and distribution costs.

- **Design Optimization**

As noted in the discussion on configuration, a range of ACR adaptations can be considered, varying in electricity and steam output and steam pressure. The lowest cost ACR configuration may not exactly match the lowest cost oil production configuration and vice versa. To obtain the best application, the lowest total project cost should be considered, ideally by a joint process of optimising the total facility configuration.

- **Water Access**

The northern Alberta oil sands region is an area with limited water sources, and now an increasing industrial demand. It will be necessary to configure any individual project to ensure minimal use and diversion of local water sources, so that overall regional water use planning guidelines can be met. This will particularly affect the design of electrical production elements of the plant.

5. Conclusions

The need for clean, sustainable energy supply to enable the full-scale exploitation of Alberta's oil sands reserves has been discussed on many occasions over the years. Now, the depletion of conventional North American oil and gas resources, the ratification of the Kyoto treaty and parallel concern over air quality balancing the need to make the most effective use of Canada's energy resources, all increase the relevance of a nuclear energy solution.

The ACR, an advanced, affordable development of the CANDU reactor family, presents an economically attractive, adaptable option, which can be adapted to wide variations in configuration to meet individual oil-sands project specifications. Recent studies have established that ACR offers a cost advantage over the current energy source, natural gas. Studies of two different configurations give consistent results indicating about a 10% cost advantage for ACR over natural gas, at a relatively low-end natural gas price assumption.

Because nuclear is a zero-emissions operating technology, ACR offers air-quality and climate change benefits as well, which can translate into a further significant economic benefit. For example, credit for foregone SO_2, NO_X and VOC's emissions would be worth 3-4% in cost reduction, while full credit for CO_2 emissions reduction, at $15/tonne, would have a value about 18%.

Already, studies done to date confirm that an ACR energy supply is feasible; offers significant cost advantage; provides clean air and CO_2 mitigation benefits; and can be adapted to the needs of oil-sands projects.

This work confirms that an ACR, sited as part of an oil-sands production facility, is a practical proposition. AECL will pursue further studies to explore how to gain the maximum benefit from this important energy option.

References:

1. J.W. Love, K.F. Hau and T. Mahendralingam "Design Characteristics of ACR-700" CNS 2002

Retubing Point Lepreau

by L. Nosella[1], J.M. King, D. Poss[2], R. Baker[3]

Ed. Note: *The following paper was presented at the 24th CNS Annual Conference in Toronto, June 10, 2003, under the original title "Planning of the Retubing of the Point Lepreau CANDU 6 Nuclear Generating Station".*

Abstract

All 380 fuel channels, calandria tubes and portions of the lower feeders will be replaced during the upcoming refurbishment of the CANDU 6 nuclear generating station at Point Lepreau, New Brunswick, in order to extend the life of the station by an additional 25 to 30 years. The task of replacing these components has been given the generic name of Retube. Conceptual design and planning of the Retube processes and tools has been underway for the past several years. The design effort has taken into consideration very stringent process duration constraints. The conceptual design effort has been successful in developing a baseline process that satisfies these constraints. This paper provides an overview of the Retube planning process, including a discussion of some of the more important design inputs and constraints that were considered. The results of the design process, i.e. the baseline process, are summarized as well.

Introduction

All 380 fuel channels, calandria tubes and portions of the lower feeders will be replaced during the planned 18 month refurbishment of the CANDU 6 nuclear generating station at Point Lepreau, New Brunswick. The task of replacing these components has been given the generic name of Retube. Conceptual designs have been developed for the fuel channel and calandria tube replacement process, the feeder replacement process and the Retube support facilities. The processes and estimated durations have been entered into an integrated project schedule, which meets the Retube contractual requirements.

Background

Point Lepreau Generating Station has operated well since start of commercial operation in early 1983. With a lifetime capacity factor of about 83% (up to the end of 2002), it has proven to be an economic and environmentally sound electricity provider, and has had a significant positive socio-economic impact in southern New Brunswick.

The most significant issues contributing to the need to refurbish the reactor are associated with the pressure tubes and feeders. The pressure tubes are exposed to high neutron fields and hot pressurized heavy water coolant. Consequently, the tube material undergoes a variety of metallurgical changes that eventually results in the tubes reaching their service limits. Based on an assessment of remaining pressure tube life, it was determined that Retube would be required at Point Lepreau in 2007 or 2008.

In addition, it was recognized in 1996 that the outlet feeders at Point Lepreau were experiencing accelerated flow-assisted corrosion at a location immediately downstream of the channel outlet. The resultant wall reduction limited the life of these components such that replacement was required in the same time frame as the pressure tubes.

Process efficiency was another driver in the selection of which reactor components should be replaced during the Retube. For example, calandria tubes will be replaced, not only due to concerns about the ability of the original tubes to survive the extended service life, but because the sag of the existing tubes is a significant impediment to the installation of new fuel channels. In a similar vein, it was recognized that feeder removal would simplify fuel channel and calandria tube replacement by eliminating the need to manipulate feeders on the reactor face. Feeder manipulation was a major source of lost time during previous large-scale fuel channel replacements.

Scope of the Retube

AECL has been contracted by New Brunswick Power to provide complete project

1 Atomic Energy of Canada Limited, Sheridan Park
2 Atomic Energy of Canada Limited, Chalk River Laboratories
3 New Brunswick Power

28th CNS/CNA Student Conference
Winning Doctoral Level Paper

Properties of the Passive Films on Ni-Cr-Mo Alloys

by A.C. Lloyd[1], J.J. Noel, N.S. McIntyre, D.W. Shoesmith
University of Western Ontario

Abstract

Ni-Cr-Mo alloys are among the most corrosion resistant materials known, showing exceptional localized corrosion resistance under extreme industrial conditions. Accordingly, one such alloy, Alloy-22, is a candidate material for the outer sheathing of nuclear waste packages for the Yucca Mountain repository, Nevada, USA. We briefly report our results on the passive behaviour for a series of Ni-Cr-Mo alloys, with the emphasis on determining if there is a temperature dependence associated with it. The change of passive corrosion rate with temperature is a critical parameter required for long-term performance assessment calculations. The results show that alloy C22 performed better than the other members of the C-series of alloys under acidic conditions. This indicates that its selection as a waste package material is appropriate, and that it possess the potential for long-term containment of radio-nuclides.

Introduction

The candidate material for the fabrication of nuclear waste containers for the Yucca mountain repository (NV, USA) is Alloy-22 (UNS No. NO06022), one of a series of versatile, highly corrosion resistant Ni-Cr-Mo alloys. The ability of such an alloy to withstand the environment within a waste repository will ultimately depend on the susceptibility of the material to localized corrosion at elevated temperatures under potentially aggressive redox conditions. However, if localized corrosion can be shown to be unlikely under repository conditions, the long-term performance of the package will be determined by its passive corrosion behaviour, and how the rate of this process changes with temperature (which will change considerably over the lifetime of the waste package). While the passivation of these types of alloys is known to be responsible for their resistance, a better understanding of the phenomenon is warranted. The research outlined here investigates how the compositional and structural properties of the oxide films on a series of Ni-Cr-Mo alloys, including Alloy-22, adapt to changes in passive and corrosion behaviour. A primary goal is to identify the alloy best able to maintain passive behaviour over the long time periods (thousands of years) required for nuclear waste containment.

Previous studies have shown that the presence of an inner oxide layer rich in Cr (barrier layer) is primary factor in enforcing passivity on Ni-Cr and Ni-Cr-Mo alloys (1,2,3). The role of Mo in enhancing corrosion resistance has been described by several different models which include; the preferential deposition of Mo at local defects on the alloy surface to block dissolution sites (4,5), the formation of a cation selective MoO_4^{2-} layer in the exterior regions of the film resulting in a bipolar film that stabilizes the oxide phase (6), and the participation of Mo in the formation of a protective salt layer (7). The role of W in the films of Ni based alloys has not yet been studied in detail, however the solubility of W in acidic solutions is 2 to 3 orders of magnitude lower than that for Mo (8) and the dissolution rate of a tungsten-enriched oxide surface subjected to a low pH environment would be expected to be lower than one simply enriched in Mo.

Experimental

Haynes International, Kokomo, Indiana, donated the alloys used in this study. Their compositions are shown in Table I. The electrolyte used in all experiments was a solution of 1.0 mol·L^{-1} NaCl + 0.1 mol·L^{-1} H_2SO_4 (pH 1) prepared using reagent grade chemicals with ultra pure deionized water (resistivity of 18 MΩ·cm) and deaerated with ultra high purity argon gas. Acidic conditions were chosen, not to simulate possible repository conditions, but to more readily observe the balance between film formation and dissolution processes that might be expected over very long exposure periods. Details of the electrochemical techniques and time-of-flight secondary ion mass spectrometry (TOF SIMS) depth profiling methods used have been described previously (9). All potential values in this paper are reported against a Ag/(0.1 M) AgCl reference electrode.

Two types of experiments were carried out. In the first set, each specimen was fixed in an epoxy resin allowing only a circular face of 0.785 cm^2 to be exposed to the electrolyte. Each sample was then wet-polished with silicon carbide paper from 180 to 1200 grit finish, ultrasonically cleaned in methanol and rinsed in ultra pure deionized water. Samples were subsequently stored in a desiccator at room temperature for 2 to 3 days prior to experimentation. Since the primary interest is the response of already passive metal to these changes, we have used laboratory-exposed specimens rather than clean metal ones. Potentiostatic polarization experiments were performed at 500 mV. Prior to polarization, the corrosion potential was

1 Paper was presented by Amy Lloyd

recorded at 25°C for one hour. During polarization, the temperature was raised from 25°C to 85°C in increments applied every 10 to 12 hours. After completion of the electrochemical experiment, each specimen was rinsed in ultra pure deionized water and removed from the epoxy resin. The specimens were subsequently analyzed by TOF SIMS.

In the second series of experiments, rather than seal the electrode in epoxy, the connecting rod, connection point and top of the electrode were painted with a water and heat resistant sealant. This sealant was not immersed in solution, which avoided problems of crevice corrosion in the resin-specimen gap encountered in the first experimental series. The electrodes were polished to 1 mm, ultrasonically cleaned in deionized water for 10 seconds, and then placed immediately into solution. The open circuit potential at 25°C was recorded until a steady-state potential was reached (~80 to 150 hours depending on the alloy) and electrochemical impedance spectroscopy (EIS) from 10^5 to 10^{-2} Hz performed. The temperature was then raised to 75°C and the open circuit potential again recorded until a steady-state was reached. Once a steady corrosion potential was attained, another EIS was recorded followed by application of an applied potential of 350 mV for 3 days. After polarization, the open circuit potential was again recorded and a final EIS spectrum taken. On completion of the electrochemical experiment, each specimen was rinsed in ultra pure deionized water. Specimens were subsequently analyzed by TOF SIMS.

Table I - Chemical Compositions Based on ASTM Standards

Alloy Name	Nominal Composition (wt%)					
	UNS No.	Cr	Mo	W	Fe	Ni
C22	NO6022	22	13	3	3	56[a]
C2000	NO6200	23	16			59[a]
625	NO6625	21	9		5*	62[a]
C276	N10276	16	16	4	5	57[a]
C4	NO6455	16	16		3*	65[a]

[a] As balance
* Maximum

Results

Polarization as a Function of Temperature

Figure 1 shows the current values recorded at the end of the 10-12 hour period at each temperature for all alloys at 500 mV. The passive current densities for all alloys exhibited a temperature dependence, although a clear difference between high- Cr (>20%) and low-Cr (< 20%) alloys was apparent above 45°C. A separation in passive current density between C22 and C2000 was observed at 85°C suggesting an influence of W, present in C22 but not in C2000, on the passive current. Also at this potential, C4 initiated localized corrosion at 75°C while C276 did not,

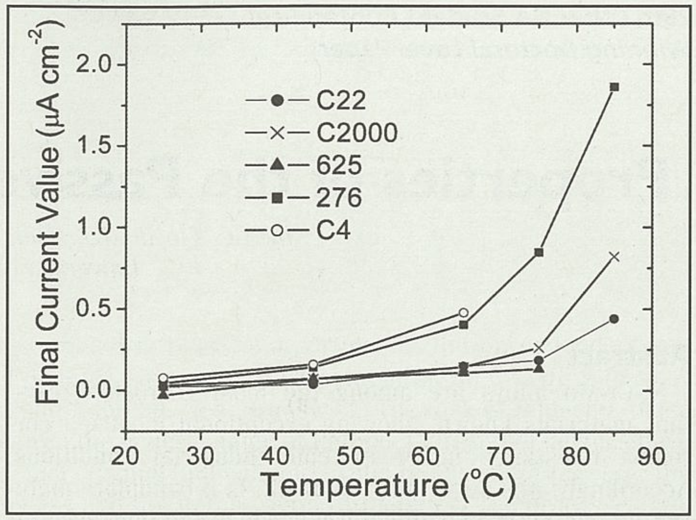


Figure 1 - Current Density Values Recorded at the End of Each Temperature Period For All Alloys During Polarization at 500 mV.

again this may be due to the influence of W in C276. The only other alloy to initiate crevice corrosion at this potential was the low-Mo alloy, 625, which initiated localized corrosion at 85°C. For both C4 and 625, localized corrosion was limited to the region of the resin/specimen contact. It is likely that expansion of the resin with temperature led to its separation from the specimen and the creation of an occluded site, within which a susceptible alloy could initiate crevice corrosion.

At this potential, the effects of the different alloying elements were marked, hence the TOF SIMS analyses taken after electrochemical treatment provide insight into alloying effects on oxide composition and structure. Two representative TOF SIMS profiles acquired after electrochemical treatment at 500 mV are given in Figure 2a and 2b for C22 and C4, respectively. The profiles show the general trends observed in oxide formation for high- and low-Cr alloys. High-Cr alloys, such as C22, were able to segregate Cr and Ni to the inner boundaries of the film, with Mo and W located mainly in the outer regions of the film. The low-Cr alloys however, were not able to achieve such a high degree of segregation, with the Mo signal extending to the inner regions of the film. As well, the high-Cr alloys consistently produced thicker films than the low-Cr alloys. Film thickness was estimated by measuring the width at half-height from 0 nm to the inner edge of the widest peak of the profile.

The degree of oxide segregation can be represented by the Cr/Mo signal intensity ratio at the oxide/metal interface for each alloy. Figure 3 shows that as oxide segregation was enhanced (a higher Cr/Mo ratio), the oxide thickness increased. This suggests that the degree of segregation of the oxide directly corresponds to an alloys ability to thicken its oxide film. Figure 3 also illustrates how the enhanced segregation (and resulting thicker oxide) decreased the passive currents for these alloys. The two low-Cr alloys

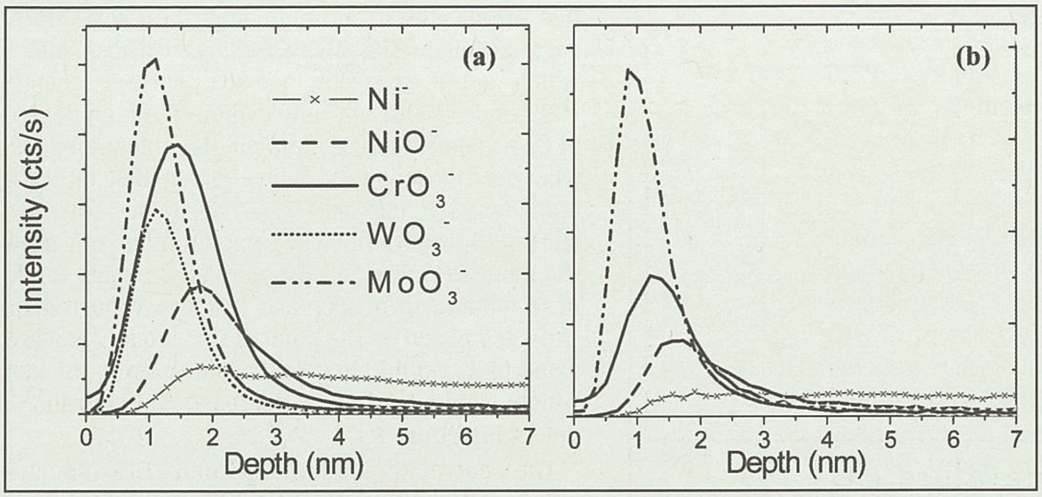


Figure 2 - TOF SIMS Depth Profiles Taken After Electrochemical Treatment at 500 mV for (a) C22 and (b) C4

showed the least amount of segregation, with the low-Cr no-W alloy, C4, initiating localized corrosion in the resin gap. C22 had the most segregated film, the thickest oxide film, and hence the lowest passive current density. Only the C-series alloys are shown in Figure 3, since a relatively large ratio was obtained for 625 compared to C22 and C2000, which only reflects the larger Cr/Mo ratio in the bulk composition of this alloy (Table I).

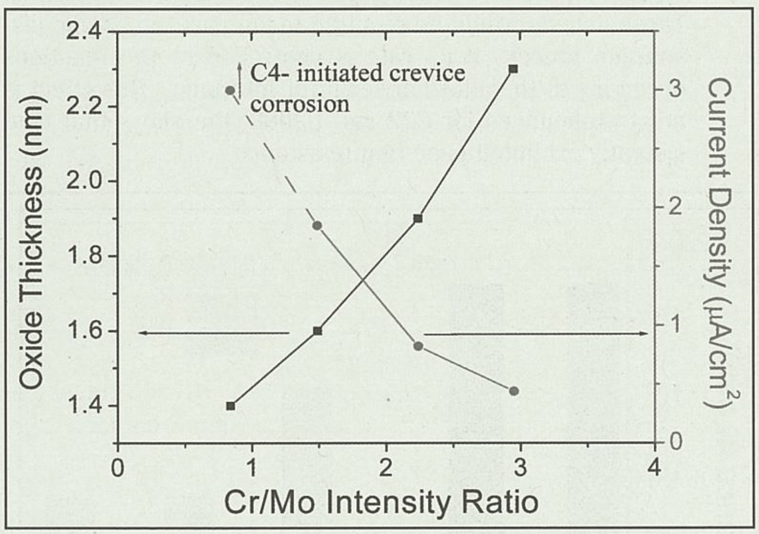


Figure 3 - The Effect of Oxide Segregation and Oxide Thickness on Passive Current Density

Open Circuit/ Polarization/EIS Experiment

Figure 4 shows the steady-state corrosion potential achieved by each alloy during the initial open circuit measurements. While all alloys had positive potentials at 25oC, the low-Cr alloys (C4, C276), and the low-Mo alloy (625) showed a drastic drop in potential on increasing the temperature to 75°C.

Although not shown, alloys C22 and C2000 experienced a drop in potential to 0 mV upon heating the solution, however, both alloys were able to recover, slowly reaching steady-state values close to those measured prior to heating. The remaining three alloys dropped to the values shown in Figure 4, reaching steady-state rapidly.

Impedance data was fit with one or two time constant circuits as required. In the case where a one time constant fit was observed, the film resistance is indicated as $R_{film.}$ For a two time constant fit, R_{pore} represents the resistance of the pores or defects present within the film and R_{pol} is the polarization resistance for the corrosion process at the base of pores or defects. Figure 5a shows the values of the film resistance as found from the equivalent circuit fits at 75°C. These are consistent with the observation of a separation in open circuit behaviour between the alloys. The three alloys for which E_{corr} decreased on heating had R_{pore} values several orders of magnitude lower than the R_{film} values for C2000 and C22. The absence of a second time constant in the EIS spectra for C22 and C2000 is a good indication that pores or defects were absent or extremely tight, and hence undetectable, in these alloys. The fact that the E_{corr} for 625 also dropped to a low potential, and the EIS showed the development of a defective film, indicates that the Cr content alone (similar for the three high-Cr alloys, Table I). was not the only feature that allowed C22 and C2000 to avoid degradation.

After polarization at 350 mV the EIS data for all alloys, except C4, were fit to one time constant. The resistance values calculated from the fitted EIS spectra and displayed in Figure 5b (right axis), show that with the exception of C4, all alloys increased the resistance of their films by eliminating defects during polarization at 350 mV. This is especially so for 625 and C276. The fact that C276 develops a high R_{film} value after polarization suggests that the presence of W was an important influence. By contrast, two time constants were needed to fit the EIS spectrum for C4, which does not contain W.

Figure 5b also illustrates the importance of a segregated film. The higher the Cr/Mo intensity ratio (as determined from TOF SIMS analysis) observed, the thicker and more resistive the oxide films. If the film was not segregated (i.e., in the case of C4, where Cr/Mo ratio < 1) then the film resistance was very low, and in fact a two time constant EIS spectrum was observed for this alloy. However, the remaining alloys showed some degree of segregation (Cr/Mo >1) and thus much more resistant films. The data for 625 is displayed on

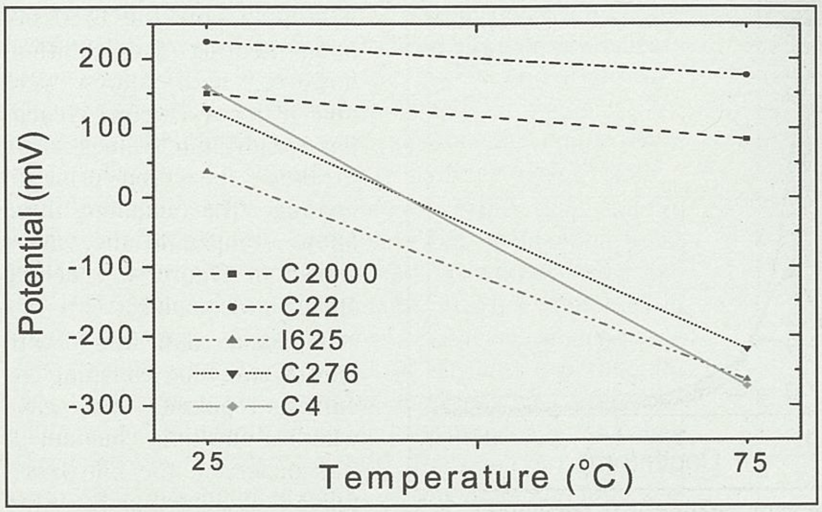


Figure 4 - Steady-State E_{corr} Reached by Each Alloy at Each Temperature

the plot, but again it should be noted that it is out of line with the C-series alloys due to its low bulk Mo content.

Discussion

The point defect model (10) was developed to describe the growth and dissolution of bilayer passive films consisting of a compact inner (barrier) layer at the oxide/metal interface covered by an outer (porous) layer at the oxide/solution interface. Figure 6 shows a schematic representation of the physiochemical processes that occur according to this model. During film growth, cation vacancies (V_m) are generated at the barrier layer/solution interface (2 in Figure 6) and consumed at the alloy/barrier layer interface (1 in Figure 6). Likewise, anion vacancies ($Vo^{\bullet\bullet}$) are formed at the alloy/barrier layer interface (3 in figure 6) and consumed at the barrier layer/outer layer interface (4 in Figure 6). The fluxes of cation and anion vacancies are in the directions indicated (6 and 7, respectively, in Figure 6), and although the transfer of cations from the oxide to the solution is shown as an electrochemical process (2 in Figure 6), it could also be a chemical dissolution involving the transfer to solution of a cation without a change in oxidation state (5 in Figure 6). Steady-state is achieved when the creation of defects at the alloy/barrier layer interface (3) is balanced by dissolution at the barrier layer/solution interface (5).

A potential of 500 mV is at the positive end of the passive potential region for these alloys, and appears to be a threshold potential for Cr release as CrO_4^{2-} (11). The rate of oxidative dissolution (k_2), as opposed to chemical dissolution (k_5), then becomes important in controlling the passive current. Thus, if Cr is present in the inner regions of the film, then the effects of other alloying additions (such as Mo and W) and their ability to retard oxidative dissolution become apparent. Raising the temperature during polarization increased the passive current densities on all alloys, and enhanced the Cr/Ni, Mo/W segregation in the high-Cr alloys. Those alloys which achieved a low passive current density (C22 and C2000) not only exhibited a high degree of Cr/Ni, Mo/W segregation but also thicker oxides, whereas the lower Cr alloys which had either a higher passive current (C276) or crevice corroded (C4) neither developed segregated films, nor grew thick ones (Figure 3). An increase in oxide thickness leading to a decrease in passive current is expected based on the point defect model, as a low value of k_5 would allow the oxide to grow thicker, which would lead to a decrease in the rate of defect injection, k_3.

The corrosion potentials and EIS spectra obtained for 625, C4 and C276 at 75oC showed that a defective oxide structure was present due to heating of the solution. However, polarization at a potential of 350 mV (within the passive region for all these alloys) was able to improve the film properties. This suggests that polarization enhanced the Cr/Ni, Mo/W segregation by forcing the creation of defects (an initially high value of k_3 upon applying the potential), allowing for the growth of a thicker oxide film. This highly segregated film would reduce the potential drop across the metal/oxide interface, thereby decreasing the rate of k_3, which in turn decreased the rate of formation of defects within the film. These defects would be required to support the anodic dissolution process if its rate is controlled by the reactions occurring at the alloy/barrier layer interface. This effect is most pronounced for C22 and C2000, the alloys that consistently exhibited good film resistance.

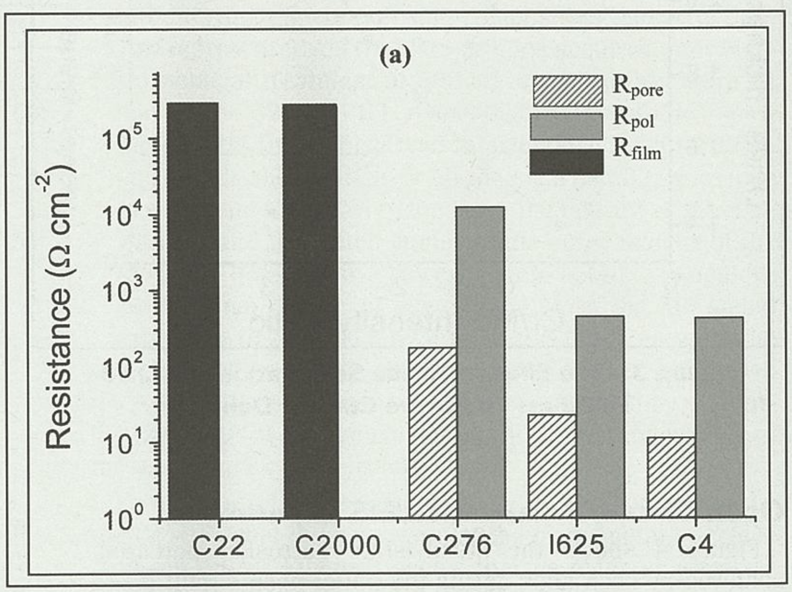
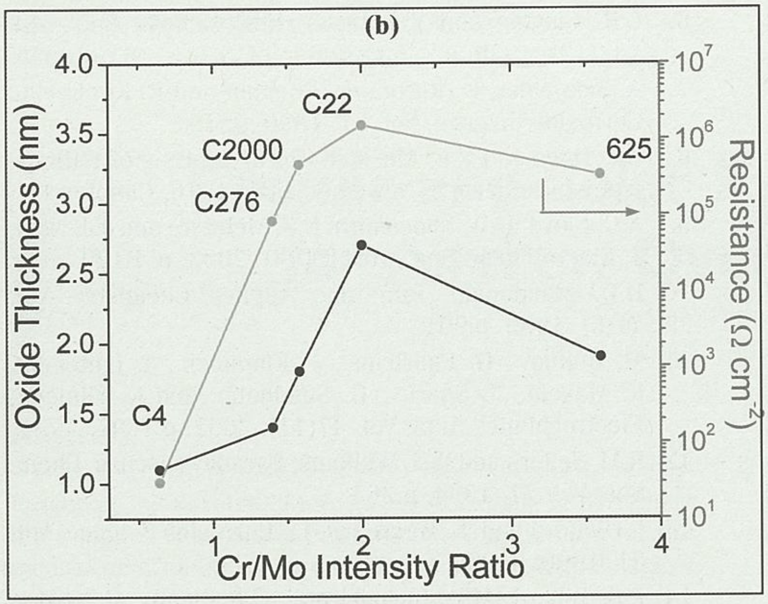


Figure 5 - (a) Film Resistance as Calculated From EIS Measurements for all Alloys After Reaching a Steady-State E_{corr} at 75°C
(b) The Effect of Oxide Segregation and Film Thickness on the Film Resistance After Polarization at 350 mV (75°C)



These results suggest that the lower passive current densities, a less pronounced temperature dependence during polarization, and the non-defective film structure obtained under open circuit conditions was due, in large part, to the development of an inner barrier layer of Ni/Cr oxide. By analogy to chromium ferrites, a nickel chromite film would be expected to have a low dissolution rate (12). However, the behaviour of 625 shows that the formation of an inner barrier layer of Cr/Ni is not the only feature important in maintaining passivity. In both experiments, although 625 was a high-Cr alloy, it behaved poorly under open circuit conditions. This suggests that a lower bulk Mo content does not allow for the natural development of a defect free inner Cr/Ni barrier layer. For the other alloys such as C22 and C2000, it does suggest that segregating Mo to the outer edges of the film offers some beneficial effect in retarding the rates step 2 and/or step 5 (Figure 6), thereby allowing for growth and subsequent defect elimination of the inner barrier layer.

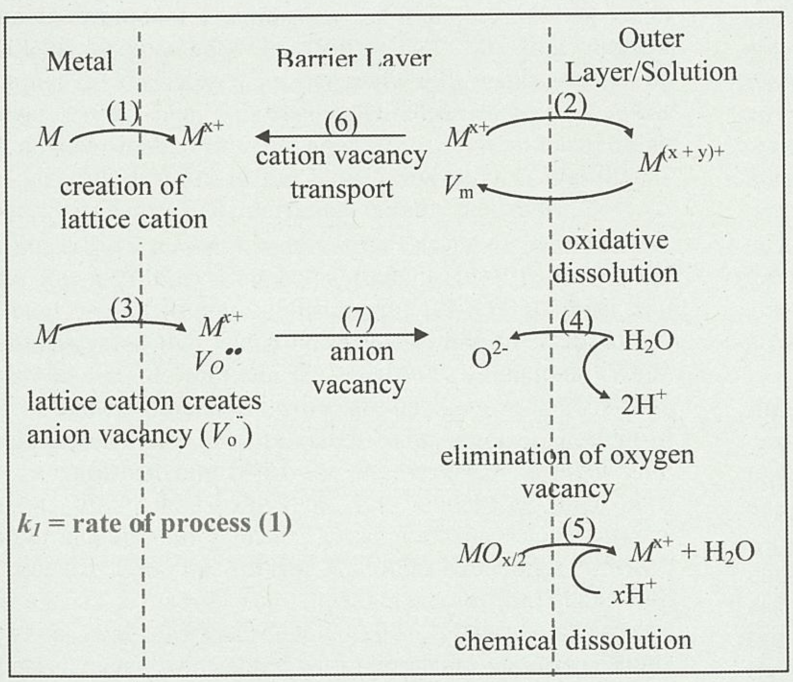


Figure 6 - Schematic Outlining the Important Processes that Occur According to the Point Defect Model (PDM)

When successful, this segregation process yields a bipolar film structure, consistent with observations made on Mo-containing stainless steels (6,13). Under gentle anodic polarization conditions, defect elimination is forced via polarization, and results in a less defective inner Cr/Ni barrier layer and the observed improvement of the oxide film on 625. Under more aggressive oxidizing conditions (500 mV, 85°C) the low bulk Mo content accounts for this alloys susceptibility to crevice corrosion, as it has been well documented that a higher Mo content is capable of suppressing crevice propagation by accumulation of Mo (4,5) or molybdates (14) at localized corrosion sites.

In its segregation behaviour within the oxide film, W behaves identically to Mo and is predominantly located in the outer regions of the film. This suggests a common role for both elements. The obvious difference in behaviour between those alloys with tungsten, compared to their non-W containing counterparts (i.e.; C22 and C2000 or C4 and C276) suggests that W aided in decreasing the rate of film dissolution *(k_2/k_5)*. An influence on the mobility of cation defects in the oxide film, as proposed for Mo by Macdonald and Urqirdi-Macdonald (15), may also be important. That such a mechanism may be operative is suggested by our observation that an influence of W is only observed once the injection of cation vacancies into the oxide, as a consequence of Cr^{III} to Cr^{VI} oxidation, occurs at 500 mV. Under acidic conditions it has been shown that W is stable as WO_3 (16), and the rate determining step for anodic behaviour is the dissolution of WO_3 (17). The dissolution rate of W at the potentials investigated in this report were found to reach a minimum between a pH of 1 and 2.6 (18), which may account for the more pronounced effect of W in the oxide under anodic polarization conditions.

Conclusions

A segregated oxide film, which had an inner Cr/Ni rich layer was mainly responsible for the low passive currents on Ni-Cr-Mo alloys. A more defect-free barrier layer accompanied by Mo and W located in the outer regions of the film resulted in a more resistive film. A high-Cr, high-Mo content (>20%) was necessary to develop this segregated oxide structure as observed for alloys C22 and C2000. The low-Mo alloy, 625 was able to form such a structure only at an applied anodic potential well within the passive region. Under aggressive conditions, 625 was susceptible to localized attack, even with a segregated oxide.

$$\frac{\dot{H}(h)}{\dot{H}_0} = \exp[-\xi_s(h-h_0)] \quad (1)$$

where h is the atmospheric depth (in g.cm^{-2}) and h_0 is equal to 243 g.cm^{-2} for an altitude of 10.6 km. The atmospheric depth in turn is related to the altitude A (in km) as follows:

$$h = \begin{cases} 1034[1-0.0227A]^{5.26}, A \leq 10.9km \\ 230.6\exp[-0.1587(A-10.94)], A > 10.9km \end{cases} \quad (2)$$

The variable ξ_s (in cm^2.g^{-1}) represents the effective relaxation length of the atmosphere, which is a function of the magnetic field's vertical cut-off rigidity (R_c):

$$\xi_s = \begin{cases} 0.0085, R_c \leq 4GV \\ -4.714x10^{-4}R_c + 0.01039, 4GV < R_c < 11GV \\ 0.0052, R_c \geq 11GV \end{cases} \quad (3)$$

Here, the vertical cut-off rigidity R_c is a measure of the ability of the Earth's magnetic field to deflect incoming radiation, and it is a function of the geomagnetic latitude; i.e. R_c is greatest at the magnetic equator (~17 GV) and weakest at the magnetic poles (0 GV).

Solar Cycle

As stated earlier, the Sun's heliosphere shields the Earth against incoming GCRs, and any variations in the heliosphere, due to changing solar activity, will impact the radiation exposure level. This is demonstrated in Figure 1, where neutron-counting levels on the ground are anticoincident with the number of sunspots (or solar activity). One can also see that the sun's activity follows an approximate 11-year cycle, which has been the case for the past 300 years.

For modeling purposes, the heliocentric potential U, a value of the heliosphere's strength derived from ground neutron monitors, represents a more reliable means to quantify the solar modulation effect. When plotting normalized ambient dose equivalent rates over the entire R_c range (Figure 2), one can easily notice variations due to the geomagnetic location (R_c), where dose rates are significantly larger at the magnetic poles. In addition, further variations occur over the solar cycle, where readings become significantly smaller during solar maximum (2001).

Over the current cycle, the solar minimum occurred around 1997. Nevertheless, through a regression analysis, sigmoid best-fit curves (known as f1 and f2) were drawn from the data collected in 1999 (the earliest data available) and 2001 as follows:[7]

$$f_1 = 2.0643 + \frac{4.5105}{1+\exp\left(\frac{R_c - 5.0016}{2.7047}\right)} \quad (4a)$$

$$f_2 = 1.1744 + \frac{3.6392}{1+\exp\left(\frac{R_c - 6.4170}{2.3073}\right)} \quad (4b)$$

Thus, using a linear Lagrange interpolation, one can now estimate the dose rate over the entire solar cycle for any value of the heliocentric potential U:

$$\dot{H}_0^U = \frac{f_2 - f_1}{220}(U-650) + f_1 \quad (5)$$

Model Improvement

Low-Altitude Correction

As indicated earlier, various failings with PCAIRE were discovered while validating the code against low-altitude flights (below 7.6 km), where PCAIRE significantly underestimated routes doses for these flights by up to 60% in some cases. Further analysis indicated that the relative relaxation length might no longer be constant at these alti-

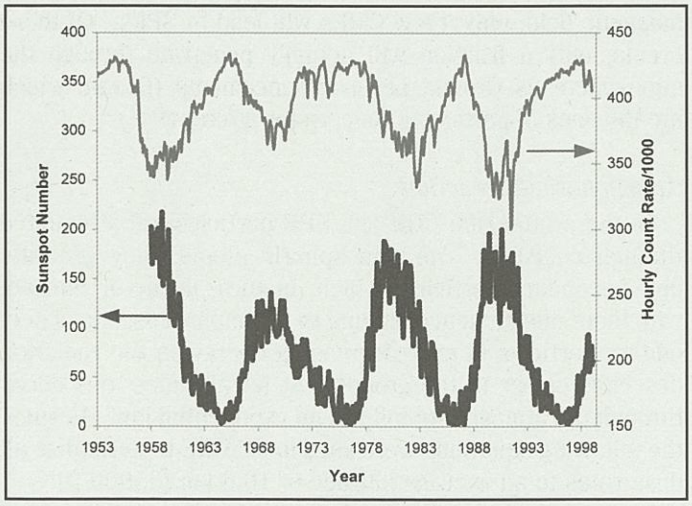


Figure 1: Neutron Count Rate Over Solar Cycle

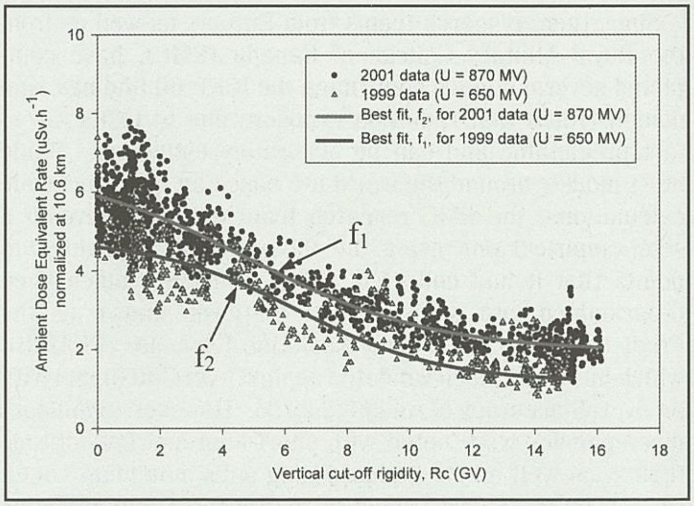


Figure 2: Geomagnetic and Solar Cycle Effects

tudes. To support this argument, extensions of the linear regression curves at Figure 3 intersect at an altitude of about 7.3 km, which does not make much physical sense. Instead, a corrected relaxation length ζ_s is proposed which better fits the measured data:

$$\xi_s^* = \begin{cases} \xi_s\left[0.6394 + 5.17x10^{-5}\exp(1.61A)\right], 4.6km \le A \le 7.6km \\ 0.6499\xi_s, A < 4.6km \end{cases} \tag{6}$$

As demonstrated in Table 1, significant improvements were made in the predictive ability of the code as a result of the correction of Equation 6.

Improved Solar Cycle Model

Although it was known that the f_1 curve (Figure 2) was not representative of the solar minimum per se, it was assumed to be close enough for linear extrapolation to lower U values. Unfortunately, validation against 1996 flight measurements, taken by the European Union's Air Crew Radiation Exposure Monitoring (ACREM) team, showed that PCAIRE consistently overpredicted the doses by as much as 100% in some cases. While Equation 5 provided good predictions for most of the solar cycle, extrapolation for U < 650 MV resulted in a significant overprediction of the dose rate. A third curve (f_3) was therefore developed using the 1996 ACREM data. However, differences between the f_3 and f_1 curves (Figure 4) were within experimental error and therefore all dose rate calculations for U < 650 MV have been frozen to the f_1 curve. In this case, the code predictions are in agreement with the ACREM results within ±20%.

Aircrew Dose Predictions for Solar Particle Events (SPE) Exposure

It is noted that aircrew radiation prediction models, such as PCAIRE, can only predict flight route doses due to GCRs. In fact, the effects from SPEs have just started to be studied by various research groups around the world, including the RMC team.

On 15 April 2001, two European teams successfully detected and measured aircrew exposure during GLE 60 on different transatlantic flights.(8) Using the data from one the flights (Prague-New York), the author developed a model, Equation 7, capable of estimating the enhanced radiation due to GLE 60 through relative comparison with the South Pole neutron monitoring station:

$$\dot{H}_{SPE}(R_c^{eff}, h) = \left[\frac{\langle \dot{H} \rangle_{\text{MDU-LUILIN}}}{\langle \Delta\% \rangle_{\text{NM South Pole}}}\right]_{\text{15 April 2001}} \left[\Delta\%(t)\right]_{\text{NM South Pole}}^{meas} e^{-\xi_{SPE}(h-h_{SPE})}\, U\left(R_c^{eff}\right) \tag{7}$$

Where the ratio of the average dose rate for the Prague-New York flight ($\langle H \rangle_{\text{MDU-LUILIN}}$ = 3.7 μSvh^{-1}) over the average percent neutron increase ($\langle \Delta\% \rangle_{\text{NM South Pole}}$ = 91%) yields a scaling factor of 0.041 $\mu Svh^{-1}\%^{-1}$. The SPE dose rate at time t (UTC) for any other flight can then be determined using the measured South Pole neutron increase as a function of time $[\langle \Delta\%(t)]_{\text{NM South Pole}}^{\text{means}}$. In this model, an effective vertical cut-off rigidity R_c^{eff} is used to account for the weakening of the Earth's magnetic field from the shockwave associated with the SPE(7). As well, the effect of altitude was considered with the term $e^{-\xi SPE(h-hSPE)}$ where ξ_{SPE} = 0.0141cm^2g^{-1} is the relaxation length for the dose rate in the atmosphere as derived from transport code calculations(7) and h_{SPE} = 235 $g.cm^{-2}$ is the average atmospheric depth of the Prague-New York flight.

The South Pole neutron monitor was selected because of its high sensitivity, which is due to its location and high altitude (2820 m). Its sensitivity is demonstrated in Figure 5 by comparing it with other stations located at altitudes of less than 200 m. The effect of the latitude in the model of Equation 7 was considered with the term $U(R_c^{eff})$, which was based on a linear regression of the peak values of the relative deviation measured for the monitoring stations in Figure 5 (less the South Pole one due to its altitude) normalized to the given quantity at R_c^{eff} =1.11 GV, which corresponds to the average R_c^{eff} for the Prague-New York flight,

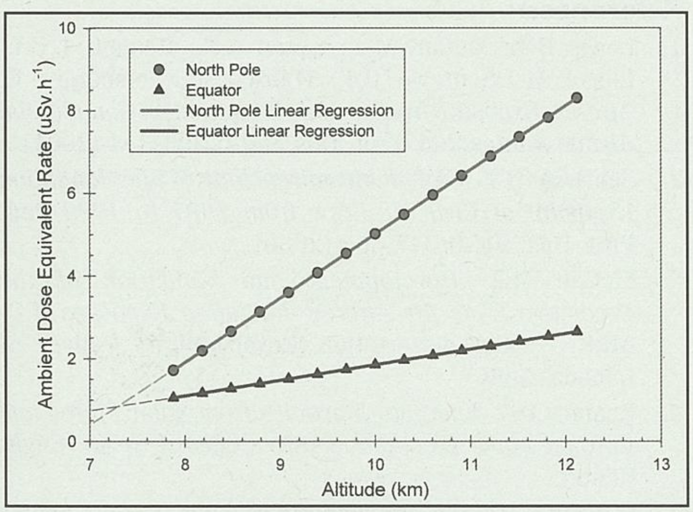


Figure 3: Ambient Dose Equivalent Rate vs Altitude

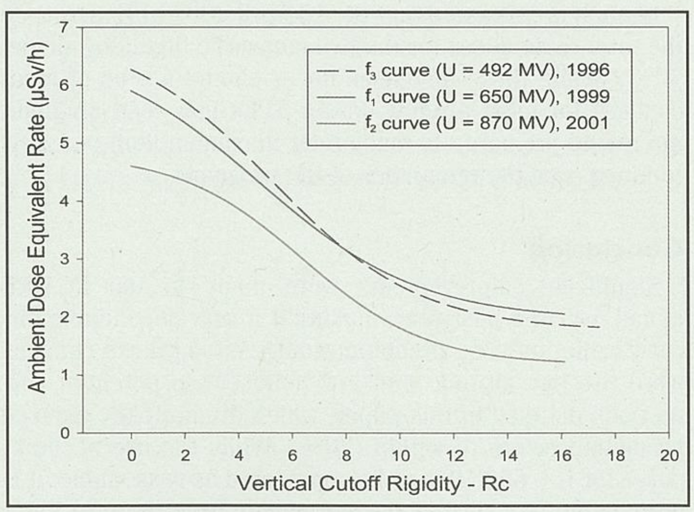


Figure 4: Dose Rate Variations Over Solar Cycle

Table 1: Comparative Results for Various Low Altitude Flights

Date	Flight	Average Altitude (ft)	Measured (uSv)	PCAIRE Uncorrected (uSv)	% Diff	PCAIRE Corrected (uSv)	% Diff
21 Jul 99	YTR-YFB	21000	7.40	4.54	-39	6.83	-8
21 Jul 99	YFB-THU	23000	5.60	3.89	-31	4.82	-14
24 Jul 99	THU-YLT	21000	1.60	1.34	-16	2.01	26
24 Jul 99	YLT-YFB	24000	7.30	6.50	-11	7.21	-1
24 Jul 99	YFB-YTR	24000	8.20	7.61	-7	8.44	3
4 Aug 99	BGF-ABJ	22000	6.20	4.07	-34	4.83	-22
4 Aug 99	YTR-PDL	22000	11.50	7.39	-36	10.40	-10
6 Aug 99	TFN-ABJ	17000	5.00	2.65	-47	4.17	-17
7 Aug 99	ABJ-BGF	18000	5.00	2.63	-47	4.00	-20
8 Aug 99	ABJ-TFN	21000	10.00	3.94	-61	5.26	-47
10 Aug 99	TFN-PDL	20000	3.60	1.98	-45	2.83	-21
10 Aug 99	PDL-YYT	17000	5.70	2.24	-61	4.51	-21

% diff. = 100 x (Predicted - Measured)/Measured

i.e. $U(R_c^{eff} \sim 1.1\ GV) = 1$ (Figure 6). For locations with Rceff values above ~3.2 GV, $U(R_c^{eff}) = 0$ zero and, hence, there is no additional radiation exposure from the SPE, which is in agreement with previous research.[5,7]

Validation for the model was considered with an independent flight (Frankfurt - Dallas) using an ACREM monitor as shown in Figure 8, where the dose prediction from PCAIRE and the newly-developed model came to within 3 % of the measured value.

As well, further validation was done for a November 2000 Ottawa-Iqaluit flight where measurements were taken by the RMC team during a severe (S4) SPE. This event was the fourth largest since 1976.[7] Despite the severity of the storm, the model predicted no additional radiation due to the SPE since only a negligible increase (~3 %) at the South Pole neutron monitor was detected for the duration of that flight.

In all, it is estimated that the 15 April 2001 SPE increased the total route doses for the two measured flights by almost 50%. While these increased doses should not be of great concern for most aircrew, larger SPEs may lead pregnant aircrew to prematurely reach their maximum limit of 1 mSv (defined over the remainder of the pregnancy).

Conclusion

Significant improvements were made to the PCAIRE model over the past year, making it a very dependable aircrew radiation dose prediction tool. Among these changes were the low altitude and low heliocentric potential corrections detailed in this paper, which dramatically reduced prediction errors to within (20%. While the use of the f1 curve for U < 650 MV can be considered as reasonable, it is anticipated that further measurements from the next solar minimum will confirm this approach.

A model for predicting the impact from solar particle radiation was also presented in this paper. It is to worthwhile to note, however, that while the early results are very encouraging, issues such as the longitudinal dispersion of SPEs around the Earth, and the consistency of the GLE 60-based model with other GLEs still require further study. In particular, more measurements must be taken in order to extensively validate the model. Unfortunately, SPEs are rare in this period of increasingly lower solar activity, and it may take several years before enough data are collected. Finally, unless several events like the GLE 60 occur over the same year, the increased solar radiation exposure should only be of concern to pregnant aircrew.

Acknowledgements

The author would like to thank the other members of the RMC aircrew radiation team, Dr B.J. Lewis, Dr L.G.I. Bennett, Dr A.R. Green and A. Butler for their assistance in his research. In addition, the author would like to thank the Bartol Research Institute (a program supported by the United States National Science Foundation under grant ATM-0000315) for providing the ground neutron monitor data.

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9. GLE 60 1-minute neutron monitor data obtained from Bartol Research Institute.
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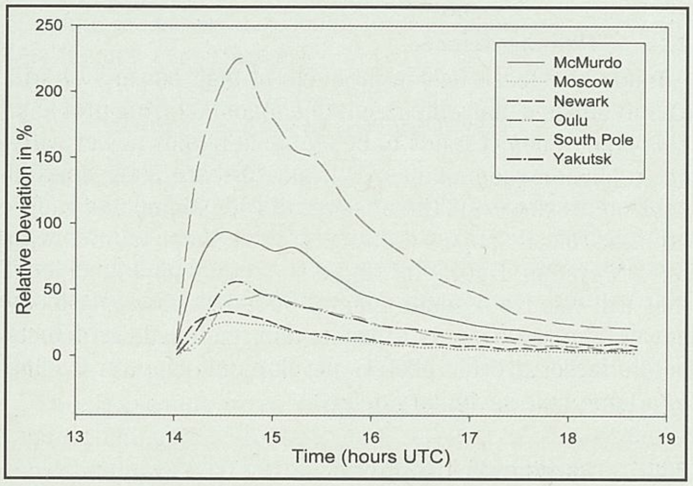

Figure 5: Ground Neutron Monitors during GLE 60[9,10]

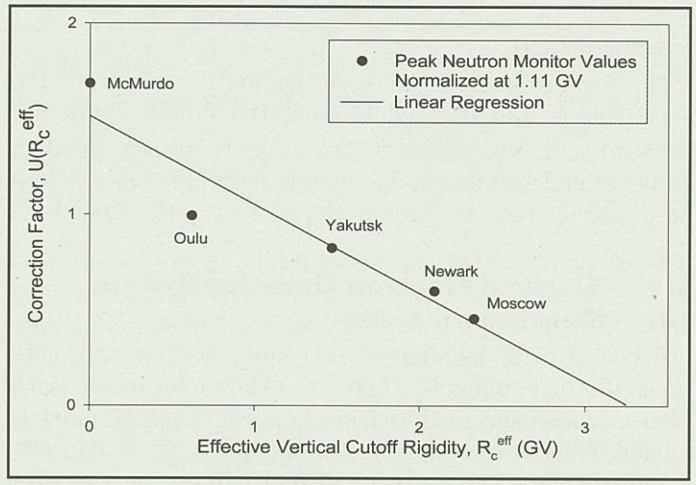

Figure 6: Correction Factor $U(R_c^{eff})$ for Latitude Effect

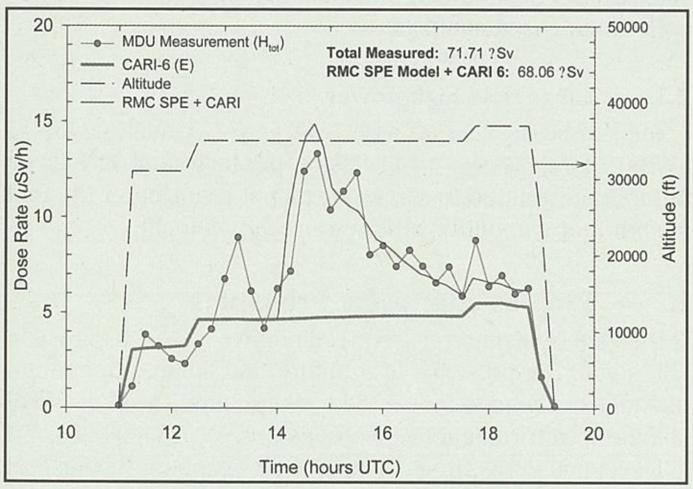

Figure 7: Model Development (PRG-JFK) GLE 60

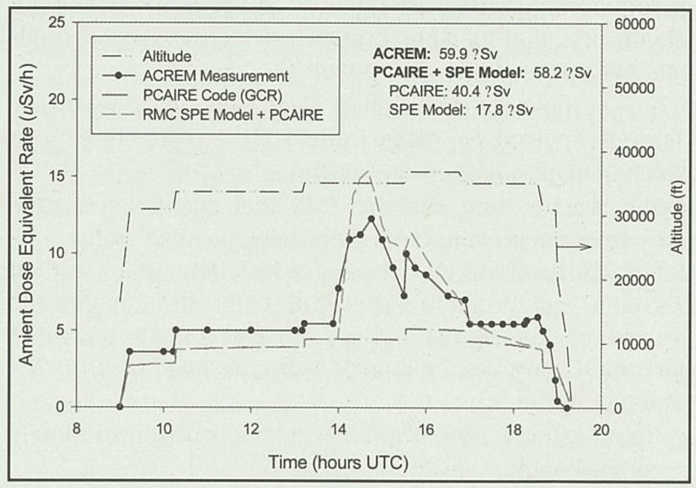

Figure 8: Model Validation (FRA-DFW) GLE 60

Investigation of the Bruce B Delayed Neutron Detection System

by Oliver Carriere
University of Ottawa (and Development Student Plant Design Engineering, Chemistry Design, Bruce Power)

Introduction

The present goal of this investigation is to improve the sensitivity of the Delayed Neutron Detector System. The sensitivity of the system is not as good as requested. A software upgrade if possible will be more favorable than a hardware upgrade because of the possible cost implied.

1. Delayed Neutron Detector System

1.1. Description of System

Bruce NGS "B" has four reactor units. Each reactor contains 480 fuel channels. There are two reactor loops. Each loop is composed of 240 fuel channels. Each channel is loaded with 13 fuel bundles, each containing 37 fuel elements (pencil). There are 6240 fuel bundles in a reactor core. Each bundle will stay approximately 1 to 2 years in the core and it is inevitable that some (< 0.1%) will crack or rupture before they are removed as spent fuel. When the sheath of a fuel element becomes defective, fission products are released into the coolant[1].

The purpose of the Failed Fuel Location System or Delayed Neutron Detector System (DN) is to identify in which channel the failure occurred.

One reactor loop contains 240 fuel channels. Sample lines from each channel (feeder corresponding to the particular channel) are taken out to a designated room (called DN room) and terminated by sample coils. The sample coils are arranged in a matrix of thirty vertical columns and eight horizontal rows. Fuel channels were assigned to a row by taking in account:

- That each row represents fuel channels of approximately similar output power.
- That each sample line must have almost the same length.

A carriage with eight detector heads and associated electronics travels horizontally, stopping at each of the thirty stations, scanning the array to get raw count. Detectors are mounted in a column and on each station they face corresponding sample coils.

2. Type Of Failed Fuel Defects:

There are three types of failed fuel defects[2].

2.1. Pinhole defects

Tends to release fission products at high power (>40-45 kW/m) and is usually the result of a manufacturing problem. This kind of defect tends to be stable at steady power without releasing radiohalides (^{137}I and ^{87}Br are main delayed neutron precursors). The absence of radioiodine and radiobromine release makes it difficult to find these failures with the DN system. Debris fretting also creates pinhole defects that will release a small amount of radioiodines at steady power. The challenge is to locate and remove these defects before larger hydride blisters develop and rupture, leading to a large hole secondary defect[3].

2.2. Large hole low power

Tend to be associated with low power pencils (<40-45 kW/m), primarily caused by debris. They release a lot of radioiodine, some tramp uranium (TU) but neither significant noble gases nor DNs[4].

2.3. Large hole high power

Tend to be associated with high power pencils (> 40-45 kW/m). It releases a lot of fission products and TU. These failures are related to stress corrosion cracking of the fuel sheath that can occur with power ramp defects[5].

3. Physics-chemistry Principles

Delayed Neutron precursor radioactive isotopes, ^{87}Br and ^{137}I, signal the presence of a failure, but some other radionuclides can lead to unwanted backgrounds. The Half-life of some relevant radioactive isotopes are ^{16}N 7.5 seconds, ^{17}N 4.1 seconds, ^{87}Br 56 seconds, ^{137}I 22 seconds. Because of this, a delay is built into the sample line before the sample reaches the detector.

Even in the absence of any failed fuel, considerable activ-

1 Design Manual Bruce Nuclear Generating Station 'B', DM-29-63105-1, Failed Fuel Location System (Delayed Neutron Monitor System) Data Acquisition and Control

2 Record & Actions from Meeting Held to Discuss Gaseous Fission Product and Delayed Neutron Detection Systems with respect to the low void reactivity New Fuel, Oct 2002.

3 ibid.

4 ibid.

5 ibid.

ity is induced in the coolant. When failure occurs, fission products are released to the coolant, the normal increase in activity is very small and only about 3% higher than the normal value. When the coolant is removed from the core, the photo-neutron emission from the decay of ^{16}N and N^{17} decreases much more rapidly than that from the decay of fission products ^{137}I and ^{87}Br. The total photo-neutron activity is at about 2% of its original value after being removed from the core for forty-five seconds. Delayed neutron emission from the fission products constitutes about 75% of this remaining activity after this delay[6].

The sample lines are so designed as to provide a transit time of forty-five seconds for the coolant to reach the sample coil from the feeder.

4. Analyses Of Historical Data

4.1. Raw Count

The raw count is the number of counts, counted by the detector of the sample coil. Each raw count is transformed into count rate. The count rate is equal to the raw count divided by the time for which the sample was counted.

The mathematics manipulation of the count rates will lead to the identification of possible defective channels.

The DN count rates from the early station operation were compared with the count rates of recent scans to investigate if any significant change occurs over time. Unfortunately, there was little historical data available to make the comparison.

The averages of 6 count rates of 131 channels present on DN scan performed in 1988 were calculated. The averages of approximately 20 DN scan, for the year 2003 was also calculated for comparison.

The variation of the count rate for each channel is:

$$\text{Variation (\%)} = \frac{\text{Recent average - Old average}}{\text{Old average}} * 100$$

The results are as follow:

Unit	Channel with increasing count rate	Channel with decreasing count rate	Average Variation (%) of all channel
5	47	9	-22.8
7	24	9	-9.6
8	37	5	-29.1

Table 1

The expectation is that the nuclear core will get dirtier with time. The results presented in Table 1 show a general reduction of the count rate of approximately 20%. The potential explanations for such a result include: It could be a hardware problem; the sensitivity of the detectors may decrease; maybe the detector don't stop exactly at the same position then the flow aren't the same.

4.2. Bruce Nuclear Generating Station "B" curve fitting algorithm

When a detector goes to all the positions of a row, the count rate should be similar. The similarity comes from the fact that the channels have similar power. An algorithm is used to fit the count rate. The algorithm will produce a background curve. The analysis of outliers is used to detect failed fuel.

The equation of the background curve is

$$\text{Background (X)} = \text{EXP}\,(D(0) + D(1) * X + D(2) * X^2 + D(3) * X^3).$$

X: the carriage position

D(0), D(1), D(2), D(3): are parameters given by the algorithm.

A ratio named "The Discrimination Ratio" is used to locate suspect channels. The ratio is equal to Count Rate divided by the background of a specific position. A ratio of 1.3 has been set to identify possible failed fuel.

4.3. Bruce Nuclear Generating Station "A" curve fitting algorithm

Bruce Nuclear Generating Station "A" has a different algorithm to fit the count rate than Bruce Nuclear Generating Station "B". Bruce NGS "A" algorithm uses weight to more correctly fit end points. The role of the weights in the data-fitting algorithm is to selectively weight more (or less) certain observations (carriage position 1, 2, 3, 28, 29, 30). This discordance resulted not because the particular observation represented a fuel defect, but rather because of the differences in the behavior of the background radiation at the row ends. To remedy the situation Bruce NGS "A" algorithm can assign more weight to the end points than to the interior points to force the background function to approximate the end points better.[7]

This algorithm was once used in Bruce NGS "B". But because of the complexity to operate the algorithm on two computers it was abandoned.

A DN scan using the Bruce NGS "A" algorithm provides more features than the scan that we have right now. It has a correlation factor to determine if the point fits the data, a delta discrimination ratio (variation of the discrimination ratio from previous scan) and it identifies and sorts the 50 most suspect channels.

A good choice of weight will ensure that the observations at the row ends will be weighted more than the interior observations unless there is a fuel defect at a row end. In which case that data is rejected in the algorithm fit. Fuel defect of Unit 5 of Unit 5 channel L07 in May 2002 was in position 30 of the third detector. This algorithm could have made this fuel defect more evident.

6 Design Manual Bruce Nuclear Generating Station 'B', DM-29-63105-1, Failed Fuel Location System (Delayed Neutron Monitor System) Data Acquisition and Control.

7 P. Sermer, Objective Assessment of DN Data for Effective Detection of Fuel Defects at BNGS, November 1988.

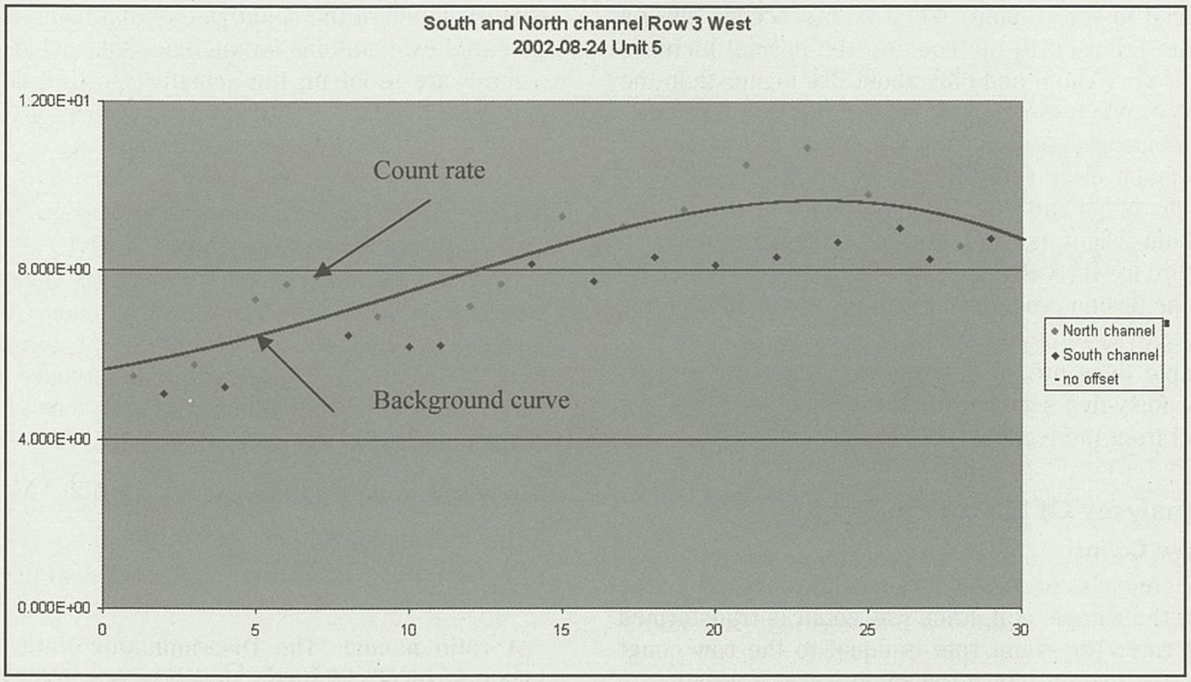

Figure 1

It is recommended that the Bruce NGS "A" algorithm be used at Bruce NGS "B" now at as a temporary measure. There is already experience at Bruce NGS "B" in the use of this algorithm.

5. Analyses Of Current Data

DN scans are performed usually over the weekend. The only available outputs of these data are in paper format. To be able to work with these data a long process of copying the data into Microsoft® Excel document was undertaken.

Each DN scan is totally independent of the previous one. Therefore, absolutely nothing takes in consideration the effect of time. To improve the sensitivity of the system the historical record of DN scans for each channel has been reviewed, the standard deviation (σ) has be calculated and trended and ratio were investigated as suggested in a meeting held at Bruce Power in 2002[8].

As a temporary measure a Microsoft® Excel template is created and applied to each channel to incorporate the effect of time. In this template the most relevant methods investigated and recommended are presented. When a method goes above its specific criterion the channel is flagged as a possible suspect. When more methods flag the same channel, this specific channel becomes a high suspect channel to contain a fuel defect. Table 2 presented below shows the Microsoft® Excel template applied to the Channel T17 of the Unit 7.

The average used is a moving average as well as the standard deviation. When a new scan is made the last value entered is deleted and the new data are inserted.

The Discrimination Ratio of a defective channel may not only go up with time. A variation of the Discrimination Ratio

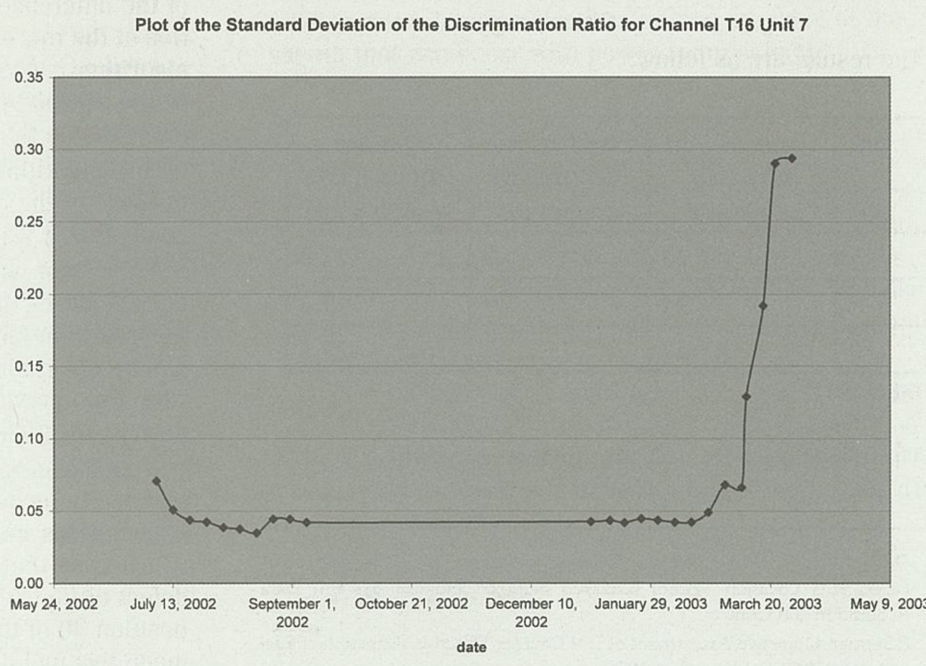

Figure 2

8 Record & Actions from Meeting Held to Discuss Gaseous Fission Product and Delayed Neutron Detection Systems with respect to the low void reactivity New Fuel, Oct 2002.

Channel	T17
Unit	7

	Date	DR	AVERAGE	STDEV	DR. AVERAGE	DR. / (AVG+Xs)	DR. / (AVG+Xs)	X
1	June 29, 2002	1.01						
2	July 6, 2002	1.11	1.06	0.07	1.05	0.87		3
3	July 13, 2002	1.05	1.06	0.05	0.99	0.87	0.82	3
4	July 20, 2002	1.08	1.06	0.04	1.02	0.91	0.89	3
5	July 27, 2002	1.02	1.06	0.04	0.97	0.86	0.86	3
6	August 3, 2002	1.07	1.06	0.04	1.01	0.91	0.91	3
7	August 10, 2002	1.02	1.05	0.04	0.97	0.88	0.88	3
8	August 17, 2002	1.06	1.05	0.03	1.01	0.92	0.91	3
9	August 24, 2002	0.96	1.04	0.04	0.92	0.82	0.84	3
10	August 31, 2002	1.00	1.04	0.04	0.96	0.85	0.85	3
11	September 7, 2002	1.03	1.04	0.04	0.99	0.88	0.88	3
12	January 4, 2003	1.09	1.04	0.04	1.04	0.93	0.93	3
13	January 12, 2003	0.99	1.04	0.04	0.95	0.85	0.85	3
14	January 18, 2003	1.02	1.04	0.04	0.98	0.88	0.87	3
15	January 25, 2003	0.96	1.03	0.04	0.93	0.83	0.83	3
16	February 1, 2003	1.01	1.03	0.04	0.98	0.87	0.87	3
17	February 8, 2003	1.04	1.03	0.04	1.01	0.90	0.89	3
18	February 15, 2003		1.03	0.04	0.00	0.00	0.00	3
19	February 22, 2003	1.15	1.04	0.05	1.10	0.97	0.98	3
20	March 1, 2003	1.25	1.05	0.07	1.19	1.00	1.04	3
21	March 8, 2003	1.03	1.05	0.07	0.98	0.87	0.87	2
22	March 10, 2003	1.56	1.07	0.13	1.45	1.17	1.29	2
23	March 17, 2003	1.75	1.10	0.19	1.59	1.18	1.29	2
24	March 22, 2003	2.17	1.15	0.29	1.88	1.25	1.41	2
25	March 29, 2003	1.52	1.17	0.29	1.31	0.87	0.87	2

Table 2

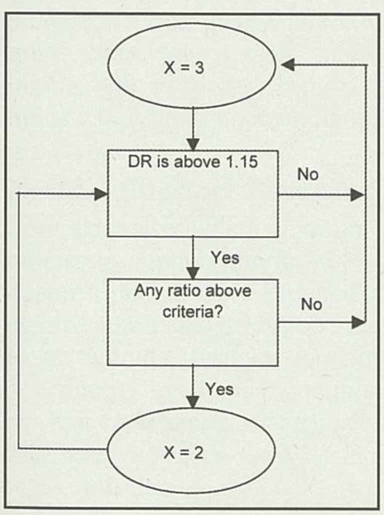

Figure 2

over a period of time may suggest a defective fuel. To take in account this kind of situation the standard deviation is trended.

Generally the discrimination ratio of a channel that does not contain a defect is equal to 1.0. The standard deviation over a long period of time will be around 0.03. The plot of the standard deviation for a non-defective channel will give a flat profile. But when a defect occurs the standard deviation should goes up and a positive slope should be observed in the graph.

5.1. Method name: DR / Average of historical DR

M. Manzer of AECL suggested that the Discrimination Ratio of a channel divided by the average of the historical Discrimination Ratio should be lower 1.1. When this ratio is above 1.1 the channel should be suspected[9]. This value is based on the expected variability in the historical average of the DR data.

5.2. Method name: DR / (Average of historical DR + σ * X)

This method is an improvement of the previous one. It takes into account the standard deviation of the discrimination ratio and also the power of the channel. The X value is present in the last row of the template that contains all the methods. The X value changes over time following the algorithm presented in Figure 2. Figure 2 show the case for a high power channel, at the bottom the X value is equal to 2. The value of X*σ give a confidence interval of 3 σ for all the channels until a method flag a specific channel as a suspect. For that channel the value of X will decreases by taking into account its channel power. The algorithm suggested is presented in figure 2. The X value of a low power channel can vary from 3 to 1 and a high power channel the X value can vary from 3 to 2. When this ratio is above 1.0 the channel should be suspected[10].

5.3. Method name: DR / (Average of historical DR + σ * X)

This method is almost the same as the one described in section 5.2. The standard deviation used in this method

9 Record & Actions from Meeting Held to Discuss Gaseous Fission Product and Delayed Neutron Detection Systems with respect to the low void reactivity New Fuel, Oct 2002.

10 ibid.

is the one of the previous scan. When the DR increases, the standard deviation will do as well. The combination of these two factors will affect the DR / (average of historical DR + X σ) method and sometimes it may miss a defect. By taking into account the previous standard deviation, the DR increases and the standard deviation stays relatively low and this method will catch the potential fuel defect. When the ratio is above 1.0 the channel is considered as a suspect channel to contain a fuel defect. In figure 2, on March 10 it becomes very clear that channel T16 may contain a defect. All methods were suggesting that this channel was containing a defect. It has been confirmed later that channel T16 did contain a defect.

6. Conclusion

Analyze of variation of the count rate for specific channel show that the count rates have decreased of approximately 20% over the last 10-15 years. Since 1988 concerns about the sensitivity of the DN system have been raised. A report about electronics of the DN system has been produced in 1995 that present ways to improve the sensitivity of the detectors[11]. An investigation could be undertaken today to see if the recommendation of this report could be applied.

I recommend to add the methods "DR / (Average + σ X)", "DR / (Average + σ X*)" and "plot of the standard deviation of the Discrimination Ratio" to the "Bruce NGS "A" algorithm. For the three known defects, that occurred in the last year, these methods were able to locate the defect. The program should be adapted to show the count rate with more precision, like it is right now in DN scan (with four significant digits). A PC should be installed in the DN room to replace the actual computer so that the operators could perform the tasks in the same place or the computers could do it automatically.

The manipulation of the data provides ratio that are good tools for the personal involved in the detection of defective fuel. The methods investigated give a better understanding of what is happening in a particular channel. The incorporation of time in the calculation increases the sensitivity and our ability to detect failed fuel.

Reference

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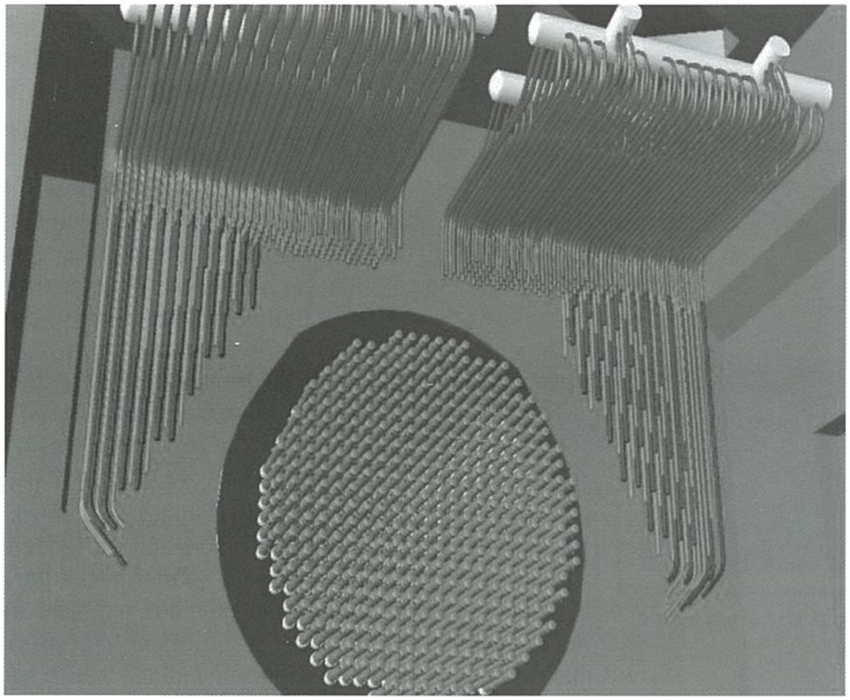

Figure I – Simplified View of the Reactor Face after Feeder Removal

management, design, procurement and site support services, including complete responsibility for the removal and installation processes of the Retube. For the past several years, AECL and New Brunswick Power have been collaborating on the conceptual design of facilities, tools and processes required to carry out this work, in anticipation of the detail design and preparation phase (Phase 2 of the project).

The reactor components to be replaced are the pressure tubes, annulus spacers, end fitting assemblies, positioning assembly components, shield plug assemblies, channel closure assemblies, calandria tubes, calandria tube inserts and portions of the feeder tubes, including the feeder tube to end fitting bolted connection components. The bellows assemblies, calandria end shield lattice tubes (including the outboard journal ring and retainers, inboard bearing sleeve and calandria side tube sheet bores), gas annulus system tubing and portions of the upper feeder tubes will remain in place and be re-used.

Retube Support Facilities

An extensive logistical system is required on site to support the Retube operation to ensure that the work proceeds safely, efficiently and quickly. Retube support operations include project management and scheduling, engineering support, quality assurance, training, materials management and other services such as change rooms and cafeterias.

To provide for these support operations, structures are required to house support personnel and equipment, and areas within the reactor and service buildings will be required for tooling and component lay down and storage. Access routes around and inside the plant will be required for movement of tooling, components and waste.

The responsibilities for supplying and maintaining Retube support services will be split between AECL and NB Power. The construction and operation of the support facilities should minimize disruption to the existing plant operations, and the facilities must be removable to allow the site to be easily returned to its pre-Retube condition. In addition, the support facilities and processes must be designed and operated in a manner consistent with station operating instructions and practices, especially in the key area of radiation protection and contamination control.

Many different design inputs were considered. Past AECL and nuclear industry experience with support facilities used at large new reactor construction projects were reviewed. Current station operating facilities and processes were analyzed to gain insight into the most appropriate ways to provide similar retube services.

The location of the support facilities was a key consideration. Facilities located within the station perimeter security fence would be most functional, since personnel would always be in close proximity to the work areas within the reactor building. However, the space available within the protected area is limited, and the construction of facilities could interfere with plant operation in the years leading up to the Retube outage.

Facilities must also be located close to the necessary services, e.g. water, electricity, active drainage and ventilation, such

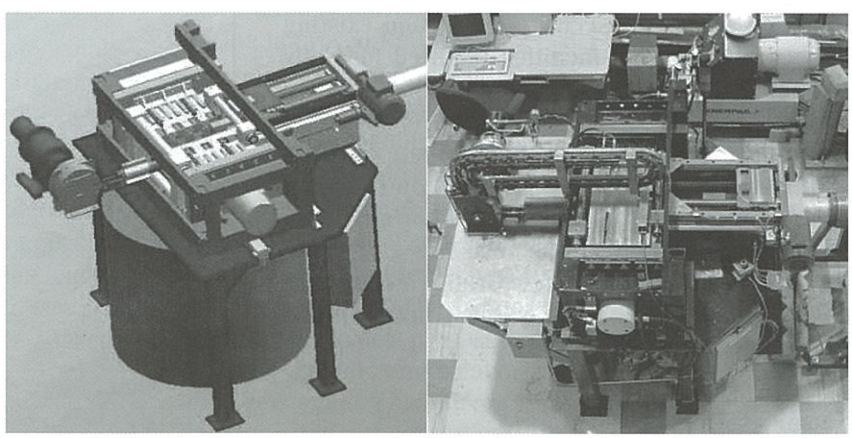

Figure 2 – Pressure Tube and Calandria Tube Volume Reduction Prototype Tool

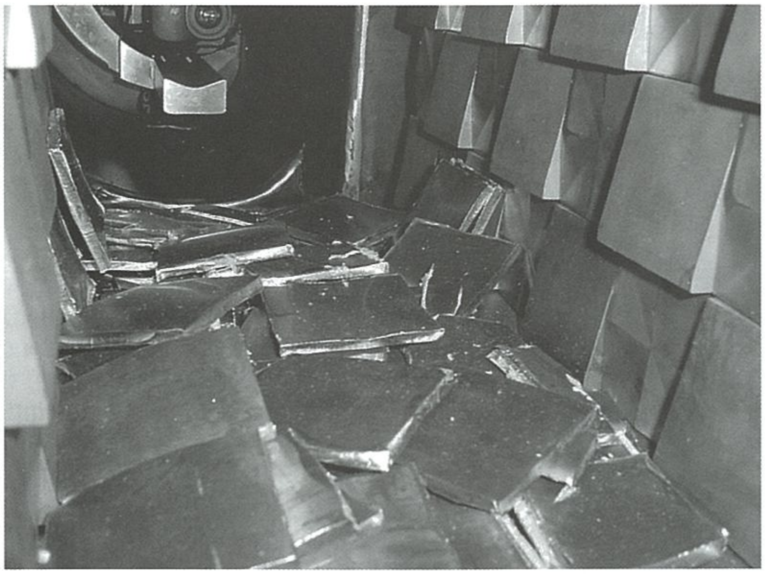

Figure 3 – Processed Pressure Tube Pieces within the Prototype Volume Reduction System Press

that tie-ins can be made as easily as possible. Many different types of commercially available structures, both temporary and permanent, are available for use. A market search was conducted to determine the optimum building type to use for the Retube facilities. Among the types of structures considered included pre-fabricated steel temporary structures, frame and fabric temporary structures, permanent buildings or existing buildings located off site. Pre-fabricated steel temporary buildings installed on concrete pads were determined to be the best selection for on site structures. Pre-fabricated steel buildings are of reasonable cost, are commercially available in many sizes, can be constructed to local building code requirements, and can be easily upgraded to incorporate special features, e.g. clean room conditions. Pre-fabricated trailer units will also be used where appropriate for smaller facilities such as offices.

The selected approach consists of a mixture of temporary structures, to be built on site within the station perimeter security fence, and existing buildings off site. The facilities required for daily operations, e.g. decontamination facility, will be located on site. New component warehouse and assembly facilities will be located off site in existing structures. These facilities are non-radiation areas and require a relatively large floor space, so it is most cost effective to use existing warehouse structures in the southern New Brunswick area for these facilities. Components will be trucked to site on a just in time basis.

Feeder Replacement

The selected feeder cut locations will clear the reactor face to facilitate fuel channel replacement, and also result in the removal of the pipe sections most affected by feeder wall thinning. The reactor face after feeder removal to the contractual cut location requirement is shown in *Figure 1*.

The conceptual design of a feeder replacement process presented considerable challenges. It became apparent early in the design effort that, due to the awkward shape of the feeder pipes, automation could not be applied. Feeders are most effectively manipulated manually, both during removal of the old section of pipe as well as during fit up of the new replacement section. A different reactor face work platform system would be required for feeder replacement than those proposed for fuel channel replacement, due to the fundamentally different nature of the two operations.

Fuel channel replacement work is most efficiently performed on a large open floor space at the same elevation as the row being worked on, and consequently a relatively large, single level work platform is required. On the other hand, feeder replacement requires smaller work areas located at different elevations that provide maximum flexibility and range of motion to the work crews without compromising their ability to manoeuvre the feeder tubes around the fuelling machine rooms. The conceptual feeder replacement work platform configuration utilizes the Fuelling Machine Bridge, a platform mounted on it, and scaffolding hung from below it. Two scissor lifts, on the fuelling machine room floor, could be used to reach the upper sections when performing horizontal feeder removal.

Lifting requirements will be satisfied by light-duty jib cranes mounted on structures attached to both sides of the Fuelling Machine Bridge. A small electric winch system could also be installed on the Fuelling Machine Bridge to lower feeders.

Accurate radiation dose assessments, and the means of reducing dose, were important considerations, especially

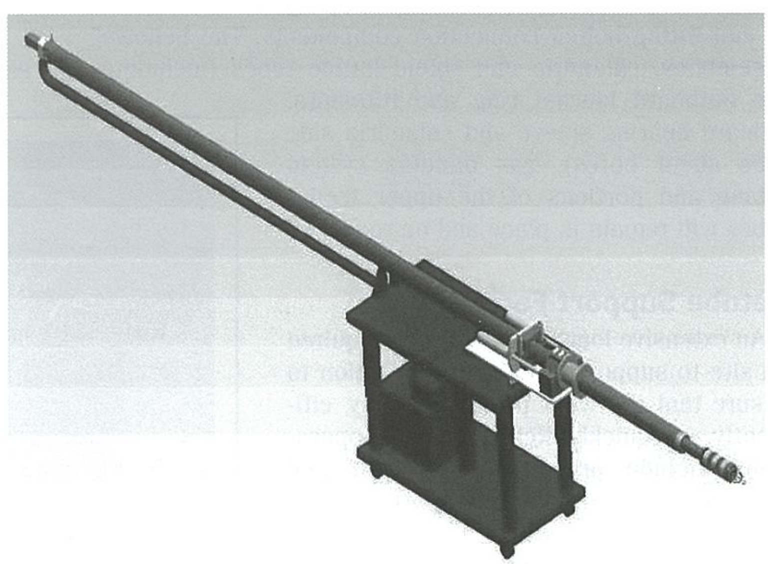

Figure 4 – Prototype Calandria Tube Guide Tool

for feeder removal. Although the radiation fields at Point Lepreau are relatively low compared to other CANDU 6 stations of similar age and operating history, the fields are still high enough to result in a relatively high exposure for this labour intensive operation performed in close proximity to the feeder cabinets. Shielding will be very difficult to implement efficiently, since there are limited means of mounting the shielding in the work areas and the time required to install and work around the shielding would impact significantly on production. As a result, simplicity and speed were the primary goals of the design of the feeder removal process.

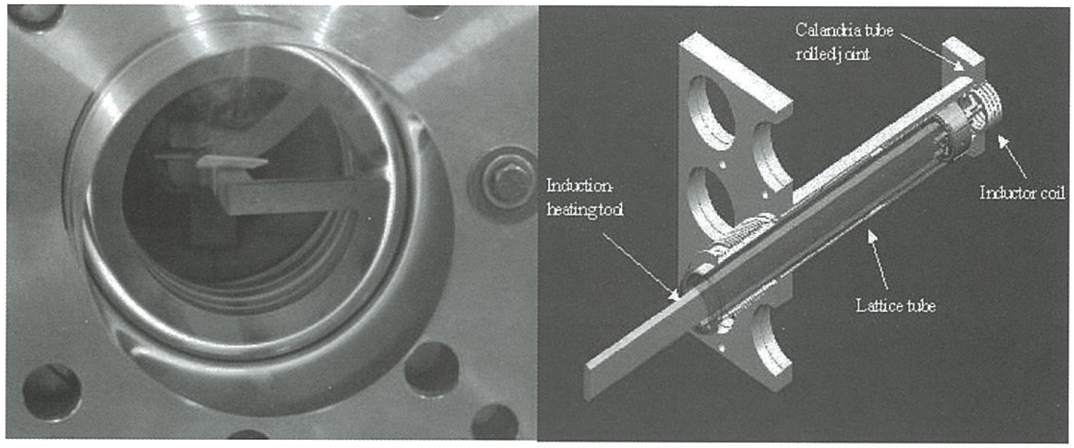

Figure 5 – Induction Heating Insert Release Equipment

Feeder Removal Plan

The removal process consists of simple, flexible manual operations that allow the work to be performed quickly, to limit radiation dose to acceptable levels.

The end fitting flexible insulation panels will be removed, disposed of, and will be replaced by new panels during the installation process. The feeder cabinet fixed insulation panels will be numbered and dismantled but will be reinstalled after fuel channel replacement. The insulation cabinet framework will be removed and most of it will be reused. Any pieces that must be cut will be refurbished or replaced for installation. The framework for the upper feeder cabinet will not be removed because no feeder replacement activities occur in this area. The support hangers attached to the cantilevers and lower feeder spacers will be cut away and new components will be used for the installation process.

Feeders will be removed one feeder at a time, in large sections wherever possible to reduce work in the fuelling machine room. However, there may be areas where the ideal method of removal will be small sections due to space constraints. Discretion will be given to the reactor face worker regarding any further cuts to be performed that would facilitate the removal of feeders. A thermal cutter is recommended for cutting the feeders because it is currently the fastest and safest option. After removal of the feeder pipe, the remaining length of feeder running up to the header will be plugged to contain airborne contamination and the cover gas that will be applied to the headers after completion of feeder removal.

Feeder Installation Plan

The feeder installation process has been modelled on proven, lower feeder installation practices used in new reactor construction. Feeder cabinet removal and re-assembly has been built into the process.

Weld preparation and inspection will be performed in parallel with the fuel channel and calandria tube replacement. The weld preparation will be installed without removing the feeder pipe plug, to maintain the integrity of the cover gas and to prevent debris from getting into the primary heat transport system.

Feeders will be installed as large, whole sections. Use of this method is justified because it minimizes the number of welds required for installation. New spacers and cantilever-suspended hangers will be installed while the feeders are being installed.

Fuel Channel and Calandria Tube Replacement

The design effort for the fuel channel and calandria tube replacement process concentrated on utilizing, to the greatest extent possible, the know-how gained by AECL, and the Canadian nuclear industry in general, during past fuel channel and calandria tube replacement operations. The other primary input into Retube fuel channel and calandria tube replacement process design was the development work already performed by AECL. AECL had been investigating improved Retube

processes for more than 10 years prior to the actual start of the Point Lepreau specific work, and by that time had already made significant progress in the development of an innovative volume reduction process for removing pressure tubes and calandria tubes.

The development program had also demonstrated that an induction heating technique could be efficiently applied to the large-scale calandria tube insert release and removal. As such, these new processes could be included in the baseline fuel channel and calandria tube replacement plan with confidence and a significant time savings could be realized for these critical operations. The remainder of the process can be performed using enhanced manual methods, some of which were based on traditional techniques developed for

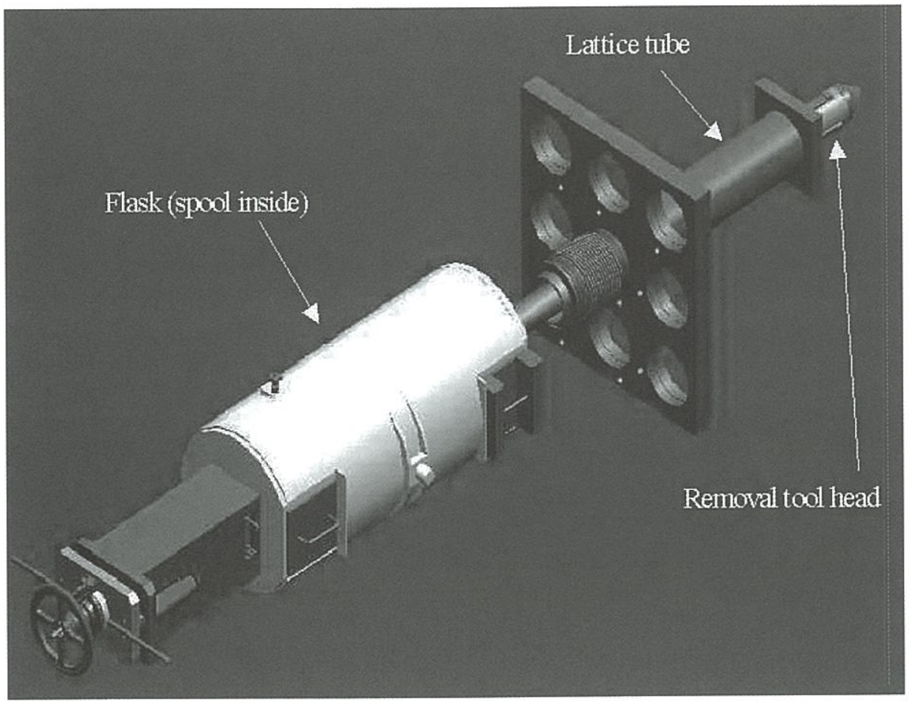

Figure 6 – Prototype Insert Removal Tool

single fuel channel and calandria tube replacements.

The other key design constraints were the measures required to limit radiation exposure, the spatial constraints within the relatively small CANDU . 6 fuelling machine rooms and maintenance areas, and their effect on access to the fuel channels and the necessary materials handling systems.

Improved Retube Development Program

Early in the Retube planning process, key areas were identified which required special attention to significantly reduce schedule, cost and risk. AECL undertook a development program to address these areas in order to produce substantial improvements to the Retubing process.

Pressure Tube and Calandria Tube Removal

The use of previous large-scale pressure tube removal techniques, or the adaptation of the single channel replacement technique to large-scale pressure and calandria tube removal operations is not feasible in a CANDU . 6 reactor. This is primarily due to the space constraints, as the time required to move large flasks around the reactor building would be prohibitive. A new process, called volume reduction was required to make pressure tube and calandria tube removal operations more economically attractive. The basic approach is to reduce the storage volume of the pressure tubes and calandria tubes at the reactor face, resulting in smaller and lighter waste containers to facilitate handling and removal from the reactor building.

An innovative technique was developed whereby sections of a pressure tube or calandria tube are fed into a specialized press. This press first crushes the tube flat and then in the same motion shears the material into small square coupons in a checkerboard fashion. After crushing and shearing a tube section, the press opens to allow the waste to fall into a flask below. The interior volume of the system will be kept under a negative pressure, with the exhaust routed through filters and active ventilation, to control any small particulates that could be created by the crushing process. Operation of the volume reduction process is done via a programmable logic based controller using automated routines and interlocks to prevent out-of-sequence events. *Figure 2* shows the volume reduction system, while *Figure 3* is a photo that shows the pressure tube coupons following the crush and shear operation. For processing calandria tubes, a guide tool is used to support the trailing end across the calandria and to ensure that he tube does not come into contact with the remaining core components. *Figure 4* shows an image of the guide tool. A patent has been awarded to AECL for the volume reduction technique.

A prototype volume reduction system has been built and undergone extensive qualification testing. This has involved volume reduction of full length sagged pressure tubes and calandria tubes in a mock-up, wear tests to establish cutter life, system endurance tests, and tests on irradiated pressure tube and calandria tube material.

Calandria Tube Rolled Joint Insert Release and Removal, Replacement RJ Qualification

AECL has directed a significant development effort towards establishing an efficient large-scale calandria tube replacement process. To date, only a limited number of single calandria tube replacements have been carried out, and changes were required to make this operation more efficient.

AECL initially evaluated several different techniques for releasing and removing the calandria tube rolled joint insert. A method based on releasing the insert by induction heating was selected, on the basis of production efficiency and the minimal impact it has on the physical features of the tube sheet bore. Working in conjunction with industry specialists, AECL developed and successfully tested a system capable of releasing the inserts from the rolled joint, using a single heat cycle. Formal qualification testing has been completed that demonstrate the technique as a dependable, fast, and repeatable method for releasing inserts. Heating of the insert takes only seconds, and after a short cooling period of a few minutes, the insert can be pulled out of the tube sheet with negligible force. Tests confirmed that the maximum tube sheet temperature was within acceptable levels. An additional benefit of the induction heating method is that the rolled-in section of the calandria tube is also released from the tube sheet.

Prototype tooling has been developed to deliver the inductor coil on-reactor *(Figure 5)*. AECL has also developed a removal tool that functions in conjunction with a multi-capacity flask *(Figure 6)*.

The baseline Retube process consists of 15 major sub-operations. New Brunswick Power will be responsible for preparing the reactor prior to the start of the Retube activities, e.g. de-fuelling and draining of the primary heat transport system. At turnover to AECL, the reactor will be filled with light water (to header level) with the shield plugs and channel closures installed in each channel. The major steps of the current baseline Retube process are as follows:

a) Fuelling Machine Room Preparation
b) Reactor Draining and Channel Closure Removal
c) Feeder Cabinet and Feeder Removal
d) Fuel Channel Drying and Pressure Tube Cutting
e) Positioning Assembly and End Fitting Removal
f) Pressure Tube Removal
g) Calandria Tube Insert Removal
h) Calandria Tube Removal
i) Inspection, Cleaning and Refurbishment of Re-used Reactor Components
j) Calandria Tube Installation
k) Fuel Channel Installation
l) Feeder Tube Installation
m) New Fuel Loading
n) Feeder Cabinet Installation
o) Fuelling Machine Room Clean Up

Activities have been grouped into row and face series to maximize timesavings from parallel activities while still maintaining an acceptable level of safety. A primarily manual process will be employed, however remotely operated systems will be used for certain high hazard segments of the operation. AECL is continuing to work on optimization of the process to reduce schedule duration and dose.

The "as low as reasonably achievable" philosophy in regards to radiation dose has been considered throughout the design process. For example, feeder removal has been placed as early as possible in the sequence, since the removal of feeders will reduce radiation fields in the fuelling machine rooms. Other dose reduction features of the process include grouping of "wet " operations (i.e. those that involve handling of residual water in the fuel channel) together, and remote processing of pressure and calandria tubes.

Reactor Safety Training for Decision Making

by C. Keith Scott[1]

Ed. Note: The following paper was presented at the 24th CNS Annual Conference, Toronto, June 9, 2003

Abstract

The purpose of this paper is to describe an approach to reactor safety training for technical staff working at an operating station. The concept being developed is that, when the engineer becomes a registered professional engineer, they have sufficient reactor safety knowledge to perform independent technical work without compromising the safety of the plant. This goal would be achieved with a focused training program while working as an engineer-in-training (four years in NB).

1. Introduction

The training of plant staff, other than operations staff, in reactor safety poses interesting challenges. Operations staff have a comprehensive approach to the plant and reactor safety is a part of their certification program. Technical staff are focused by discipline in their work and there are no certification requirements beyond their professional qualifications. Their knowledge of reactor safety is acquired, primarily, through work experience.

The bottom-up approach to reactor safety training through work experience has two drawbacks.

- it is a slow process and makes experience an important job qualification which may be difficult to meet; and,
- a comprehensive view is only developed after diverse work assignments, delaying an understanding of important interfaces in the earlier years.

The management system and human resource plan can address these issues. However, with a changing demographic in the work force, a top-down training approach would have significant benefits.

The purpose of this paper is to describe an approach to reactor safety training for technical staff in an operating environment. It has three objectives.

1. To enable a person to make decisions in the course of their work that do not compromise safety. That is, to make conservative decisions.
2. To integrate the training with professional development so that objective # 1 can be met within five years of graduation from university. That is, to improve human resource planning.
3. To provide training that is generic and consistent with the time commitment for work and other training. That is, to have a cost effective training program.

Section 2 presents an analysis of the need for reactor safety training to meet the above objectives. The learning objectives for the first stage of training in a top-down approach are given in Section 3. Examples of material to be used in a classroom environment are given in Section 4.

2. Analysis

The technical support functions at an operating station are lead by graduate engineers and scientists. They work in diverse areas including: engineering, nuclear safety, system performance, maintenance, chemistry, reactor physics, fuel handling, heavy water management and procurement. Each area requires specialized knowledge and skills. New employees are assigned work in a particular area and begin developing their knowledge and competence.

The development of a professional engineer/scientist assumes the graduate brings technical knowledge to the job. Practical skills in applying the knowledge are acquired through work experience and mentoring. This professional development leads through a progression of levels of responsibility and independence in performing technical work.

A standard model is summarized in Table 1. It is based on practices in New Brunswick where the P.Eng. designation is obtained after four years of supervised

1 Atlantic Nuclear Services Ltd., Fredericton, NB E3B 5C8

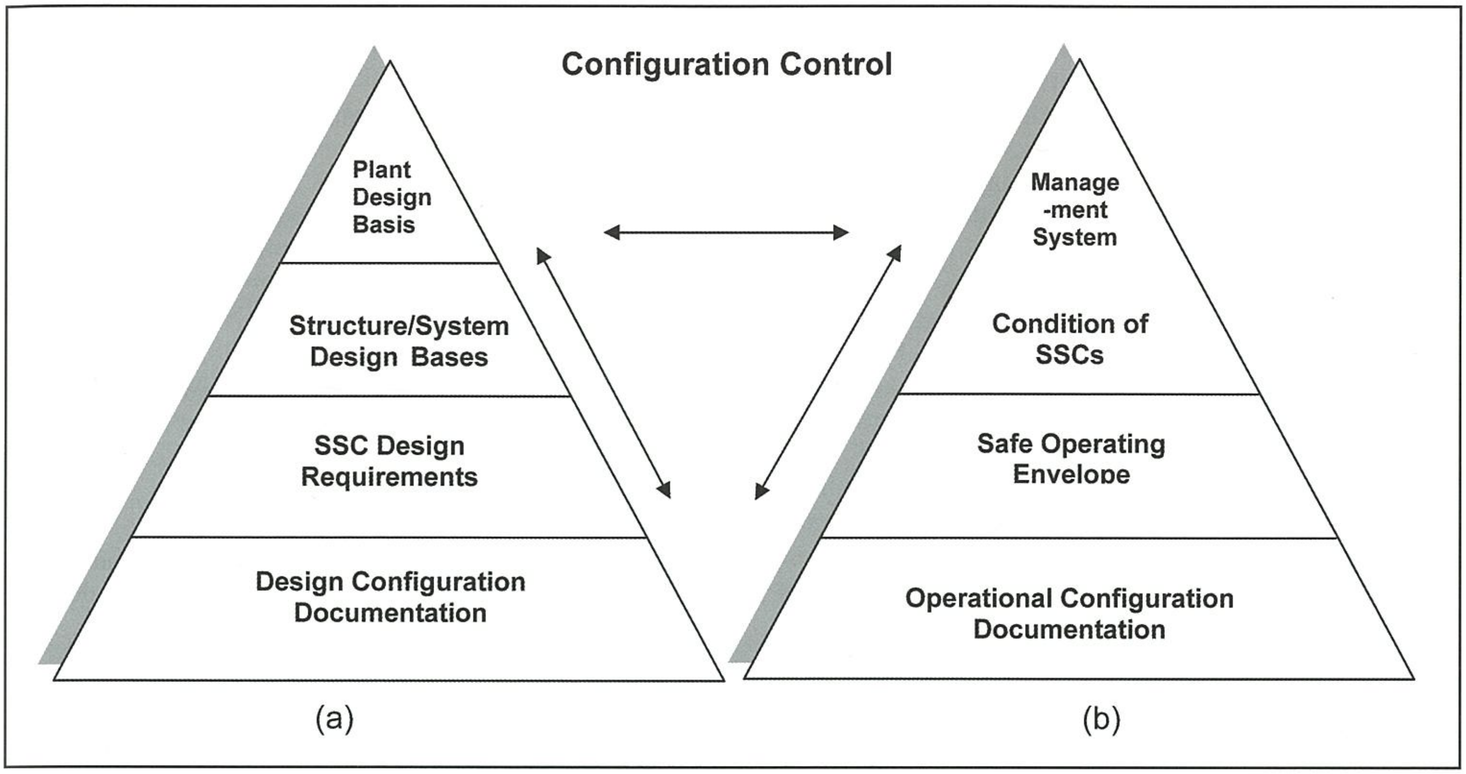

Figure 1. The Essential Elements of the Facility Configuration Management Program: (a) Design, and (b) Operation

practical experience. Table 1 includes a general description of each Experience Category in terms of the Job, Performance, Task Assignment and Supervision. Also, the nominal number of years to move through each category is included. The attributes form the basis for job performance measures.

In the first four years the supervisor takes responsibility for the accuracy of technical work done by the Engineer/Scientist-in-Training. Then the Specialist Engineer/Scientist 1 is expected to perform technically accurate work that is in conformance with policies and procedures subject to quality requirements. That is, the Specialist 1 is making decisions with respect to the direction and scope of work which have the potential to affect safety.

Examples of the types of decisions arising in the course of routine work that could impact safety include:

(a) a decision to request a safety review of a proposed design change because it does or does not have a potential impact on safety

(b) a recommendation for a course of action from a technical operability evaluation.

(c) specifying an operating configuration for a maintenance procedure.

(d) establishing action criteria for an inspection procedure.

Beyond the Specialist 1 category (> 6 years experience) the technical responsibility grows with increasing independence within the management system. At higher levels of technical competence the Engineer/Scientist is functioning independently and obtaining additional technical guidance through interaction with colleagues in the external community.

The university graduate begins with limited to no knowledge of the practical aspects of reactor safety design and operation. Since the first four years of on-the-job experience are usually focused very narrowly, it is not possible to acquire an understanding of the overall safety requirements by experience alone. That is, to have the capability to answer the question, "Does this activity have any impact on plant safety?".

To give greater decision making capability at an earlier age formal training in safety is required to supplement the practical experience. Moreover, this training should occur early enough that it can be used in practical applications before moving to the Specialist 1 category.

The over-riding safety objective is to maintain the risk to the public from the operation of the plant as low as reasonably practical (the ALARP Principle). Following Reason's approach [Ref. 1] the selection of a course of action (a decision) is considered correct or incorrect according to its consequences for the public risk.

An action is considered a correct action (right decision) if it is taken on the basis of an accurate appraisal of its impact on the risk. An action is an incorrect action (wrong decision) if it is taken on the basis of an inaccurate assessment of the incremental risk.

From the above we conclude the training needs to provide knowledge of the overall safety case for the plant and how the implications of an action for the public risk can be appraised. The training should be introductory training for the Engineer/Scientist-in-Training. It should also be a foundation for focused in depth training in topical areas as the professional development continues.

The training need can be viewed as providing guidelines for individuals to apply self-checking in the course of performing technical work.

3. Design

From the analysis of the need for reactor safety training, the goal is to design a course that will enable the trainee to take the correct course of action in performing work that has the potential to impact safety.

The training material should have the following features to fill the first level need and to be a foundation for more detailed development.

(a) It does not presume extensive knowledge of the plant nor experience with the work processes.

(b) It provides a top-down framework for knowledge of the reactor safety design that can be expanded over time with other focused training courses.

(c) It explains the relationship between the design basis, design requirements and operational configuration.

(d) It provides an overview of the interfaces and inter-relationships of the various work processes and programs with regard to safety.

(e) It provides knowledge that can be used to accurately appraise the potential for an action to affect the public risk.

Given the above features, a overview of the configuration management requirements to assure safety would serve as the basis for the training. The high level elements of a configuration management program are summarized in Figure 1 [Ref. 2,3]. The pyramids indicate the increasing level of detailed knowledge that will be acquired through experience with the design and operating configurations. Configuration control is the means of assuming the public risk remains as intended according to the licensed design basis.

Based on the elements of configuration control listed in Figure 1, the training objectives are set as follows.

Objective 1 – DESCRIBE the safety design bases for the plant, structures and systems (SSCs) and how the design requirements are derived from them.

Objective 2 – EXPLAIN the safety significance of changes to design requirements and the design bases.

Objective 3 – EXPLAIN the importance of keeping the design configuration documentation up to date.

Objective 4 – EXPLAIN the importance of the Management System in ensuring quality and conformance among the elements of the configuration management program.

Objective 5 – EXPLAIN the safety significance of monitoring and surveillance of the physical condition of SSCs to ensure conformance between the physical configuration of the plant and the design requirements.

Objective 6 – EXPLAIN the safety importance of establishing the operational configuration in conformance with the design requirements.

Objective 7 – EXPLAIN how the Safe Operating Envelope is implemented to satisfy safety requirements and maximize production.

Objective 8 – DESCRIBE how safety principles and defense in depth can be used to make conservative decisions regarding risk.

4. Development

Examples of material that has been developed to meet the training Objectives 1,6,7 and 8 are presented here.

4.1 Objective 1 – Design Basis and Design Requirements

For Objective 1 the starting point is the four fundamental safety design approaches that form the licensed design basis for the plant.

1. Design to Protect the Public
2. Design for Common Cause Events
3. Design for Defence in Depth.
4. Design for Operational Configuration Control.

The linkage between the design basis and the design requirements is illustrated in the following approach to the design basis to limit public risk. To protect the public the designer must apply two risk based design approaches:

A- the Siting Guidelines for design of the Special Safety Systems; and

B- a probabilistic safety assessment approach for the design of the other safety related systems.

Design Basis ***A - The risk to the public from the operation of the station must be within the Siting Guidelines of the CNSC.***

The Siting Guidelines specify the single/dual failure design basis accident analysis that must be performed. The purpose is to show that the design of the four Special Safety Systems is such that in the event of an accident the radiation exposure to the public is within the prescribed limits. From this safety design basis statement the designer derives the performance requirements for the Special Safety Systems. That is, the design requirements for:

- Performance capability; and
- Availability

To achieve the Siting Guideline objectives, the designer applies two design principles.

Design Principle ***Only random initial failures are assumed to occur. That is, the design must be such that the initial failure does not cause other failures of process systems or Special Safety Systems.***

From this design principle, the designer derives the following functional design requirements:

- Systems must be environmentally qualified to perform under the accident conditions; and
- Systems must be separate and independent so there are no failures as a consequence of the initial event.

Design Principle ***To meet the availability target there must be automatic initiation of the Special Safety systems in response to the initial accident event.***

From this design principle, the designer derives design requirements for

- Instrumentation and actuation

Design Basis ***B - A probabilistic safety assessment must demonstrate that the expected response of all systems to all credible upset transients leads to an acceptable public risk. At Point Lepreau these probabilistic safety assessments were called safety design matrices (SDMs).***

This design basis statement leads to the design requirements for

- Availability of standby safety related systems; and
- Performance requirements for safety related systems

To achieve the objective of the design basis statement the designer applies the following design principle.

Design Principle ***In the probabilistic safety assessment the response of systems and equipment are based on their expected performance and reliability.***

From this design principle the designer derives the basis for abnormal plant operating procedures.

Following the design basis statements and the design principles given, the designer must specify how the derived requirements are going to be implemented in the overall plant design. The course then gives examples of how the different requirements are met. It covers

– performance capability
– separation and independence
– availability
– environmental qualification
– actuation and instrumentation

Work experience will add to the knowledge of the design requirements for structures and systems.

4.2 Objective 6 – Operational Configuration

The operational configuration is the state of the SSCs at a given time as determined by the operating and maintenance procedures. Objective 6 addresses the need to understand that for the safety design basis to be satisfied at all times, the operational configuration must be consistent with the design requirements.

To implement the operational configuration the design requirements must be identified for each 'operating state'. The corresponding procedures must then ensure the operational configuration meets the design requirements with conservative margins. Figure 2 illustrates this relationship in more detail for the configuration control elements given in Figure 1.

(a) Shutdown states
(b) Operating modes other than shutdown states
(c) Precursor accident conditions that are not serious process failures but are covered by DBA. For example, a boiler tube leak, off-normal flux shape, etc.
(d) Beyond design basis accidents without significant core damage. For example, a loss of coolant accident coincident with a loss of Class IV power.
(e) The accident management plan refers to station procedures for managing the accident situation after it has been brought to a controlled state via the abnormal operating procedures. This would include station management response to the accident as well.

4.3 Objective 7 – Safe Operating Envelope

To meet safety requirements the operational configuration must be within with the design requirements for each operating state. This limit for safe operation is the Safe Operating Envelope. Objective 7 addresses the need to implement the SOE so that both safety and production requirements are met.

Taking the SOE as the licence limit for operation, equipment impairments that take operation beyond the SOE result in lost production due to outages. To maximize production the maintenance strategy has to minimize the likelihood of operation going outside the SOE. This can be achieved by taking corrective actions before impairments challenge the SOE.

Figure 3 illustrates the maintenance strategy for impairments so the production is maintained together with a more conservative safety margin. The impairment levels are based on the levels of defence in depth.

4.4 Objective 8 – Defence in Depth

With limited knowledge it is not possible to assess the consequences of an action in terms of its impact on risk. However, it is possible to know if there is potential for the risk to be affected. Objective 8 addresses this need to assess the potential impact on risk.

The conservative approach to risk management is to maintain the five levels of defence in depth at all times. Figure 3 illustrates the levels in terms of the design requirements and the operational configuration. The trainee will develop skills in applying the defence in depth in operational scenarios through work experience.

5. Conclusions

Course material has been used with operations staff in a classroom environment with success. The organization of design requirements as 'derivations' from the safety design basis gives them a rationale they would not have otherwise.

The same observation applies for technical staff. In the course of work, design requirements are encountered in isolation from their design basis. This makes it very difficult to assess the significance of the effect changes in one area may have in another. The top-down approach makes the linkages more apparent.

The configuration control process is an equivalent top-down approach to 'derive' the management system constraints on the conduct of technical work. It links plant ageing, safe operating envelope and design as a seamless view of safety.

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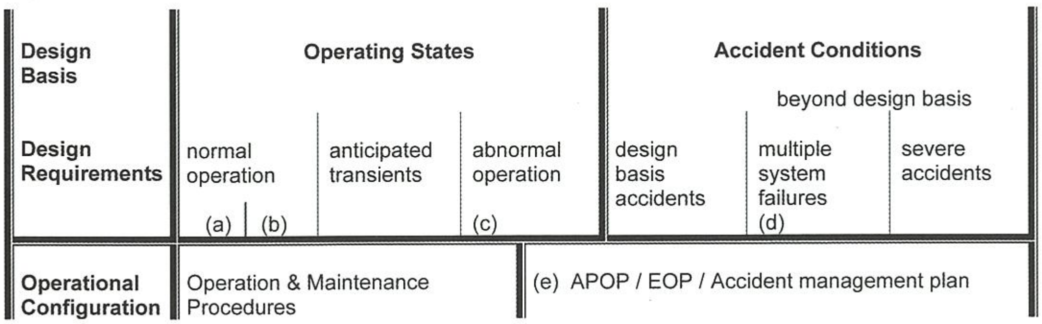

Figure 2. Illustration of the Configuration Management Requirement for the Operational Configuration to be Consistent with the Design Requirements

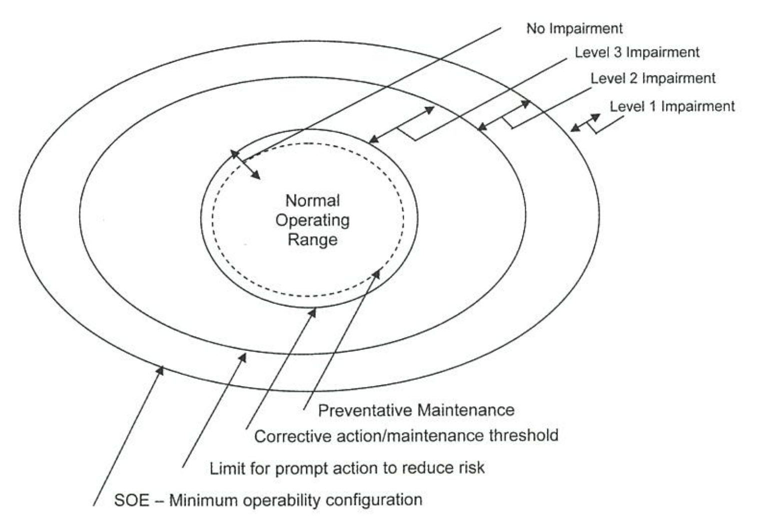

Figure 3 – Levels of Impairment and Their Operational Significance

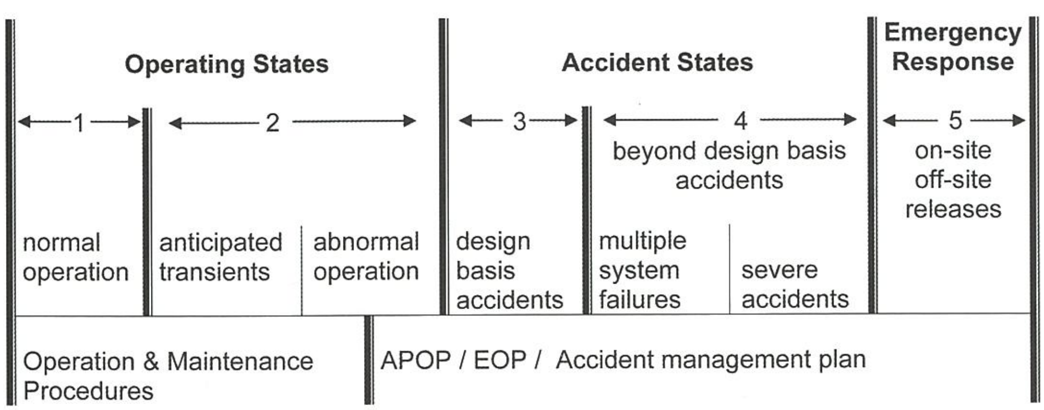

Figure 4. Levels of Defence-in-Depth [labelled 1 through 5]

Table 1: Task Assignments and Performance Expectations for Engineering / Scientific Staff by Experience Category

Engineer-in-Training / Junior Scientist 1 (<2 years experience)
- *Job:* review and summary reports, data analysis, run simulation codes, prepare design drawings and perform calculations that are not complex
- *Performance:* Work is performed with direct technical supervision.
- *Task assignments:* Specific work instructions are given with a description of the expected results.
- *Supervision:* Technical supervisor checks work in progress and upon completion.

Engineer-in-Training / Junior Scientist 2 (< 4 years experience)
- *Job:* Tasks of limited scope and complexity that require application of technical standards and the quality assurance program.
- *Performance:* Work is performed independently with access to technical supervision to resolve more difficult issues and to select procedures for non-routine tasks.
- *Task assignments:* Given detailed oral/written instructions as to the methods and procedures to be used.
- *Supervision:* Technical Supervisor monitors progress of work and performs technical reviews of work upon completion.

Specialist Engineer / Scientist 1 (4-6 years experience)
- *Job:* Tasks with specific objectives requiring investigation of a limited technical scope and addressing the interfaces with other work groups.
- *Performance:* Work is performed independently to evaluate, select and apply standard engineering methods, procedures and criteria. Judgment is used to make minor adaptations and modifications to fit the task.
- *Task assignments:* The statement of work is provided. The preparation of the work plan is an assigned task.
- *Supervision:* Technical supervision reviews work for the soundness of approach and judgments made regarding trade-offs. The completed task would be accepted as being technically accurate and in conformance with policies and procedures subject to quality program requirements.

Specialist Engineer / Scientist 2 (5-9 years experience)
- *Job:* Development, planning, scheduling and coordination of the engineering work for part of a project of significant scope or a full project of limited scope. Work is conventional but includes the requirement to resolve technical issues.
- *Performance:* Work is performed independently with competence in the conventional technical aspects of the discipline/program. Broad knowledge of the work area and good knowledge of principles and practices of related disciplines / programs.
- *Tasks Assignments:* Tasks are assigned as general instructions about expected results. Required to plan, schedule and manage on time taking into account the plans of others.
- *Supervision:* Technical supervision reviews work for completeness in addressing issues and interfaces and the soundness of judgments in defining the scope of work, methods and approach.

Specialist Engineer / Scientist 3 (> 8 years experience)
- *Job:* Supervision of a work group or direction of a technical program requiring a comprehensive knowledge of the application area and a diversified knowledge of principles and practices in related work areas.
- *Performance:* Work requires detailed knowledge of a technical subject area using advanced techniques, theories or practices. Makes independent decisions regarding technical approach and methods to be used by supervised staff.
- *Task assignments:* In addition to supervisory role, tasks include modification of work processes, implementation of new approaches to address technical problems.
- *Management:* Supervisor monitors effectiveness in managing or applying technical resources to address on-going work and emergent issues.

Senior Engineer/Scientist (>10 years experience)
- *Job:* A technical expert for a particular discipline/process or program either to supervise work or to perform the work.
- *Performance:* Work requires independent complex technical work or supervision of complex projects with results of high quality. Maintains awareness of latest developments in field and uses network of peers for advice on solutions to difficult problems.
- *Task assignments:* Given responsibility for technical work packages including content, quality, cost, schedule, and interface with client.
- *Management:* Supervisor monitors technical results, cost and schedule performance in achieving management goals.

Principal Engineer/Scientist (>12 years experience)
- *Job:* Responsibility for the implementation and management of complex technical projects / programs.
- *Performance:* Work requires knowledge of international standards and best practices for technical areas of responsibility. Maintains liaison with associations and organizations for establishing standards and addressing generic emergent technical issues.
- *Task assignments:* Project management for complex technical projects, develop management programs to address emergent design/operational issues.
- *Management:* Supervision addresses effectiveness in achieving business plan objectives.

The OECD Pipe Failure Data Exchange Project – Canadian Contribution on Data Validation

by Alexandre Colligan, Robert Jojk, Jovica Riznic[1], Bengt Lydell[2]

Abstract

The Nuclear Energy Agency (NEA) of theThe Organization for Economic Co-Operation and Development (OECD) has initiated a taken up a research project to establish an international hat would allow countries to gather pipe ing failure data collection and exchange program.the information through an international database. Thise OECD Pipe Failure Data Exchange Program (OPDE) Project has been established to encourage multilateral co-operation in the collection and analysis of data relating to pipe failure events in commercial nuclear power plants. This paper presents the brief description of the ODPE project objectives and work scope, as well as the Canadian contribution on data validation with respect to development and application of the pipe failure data collection on which OPDE is based.

Background

Piping systems are part of the most sensitive structural elements in the power plant. Therefore, the analysis of these systems and quantification of their integrity in terms of failure probability are of key importance. The failure probability of piping is influenced by the degradation mechanisms acting on it, the level of maintenance as well as the in-service inspection activities. Risk informed in-service inspections (RI ISI) are becoming the most prevalent approach in defining maintenance strategies since it is aimed at prioritizing the components for inspections within the permissible risk level, thereby avoiding unnecessary inspections. The two main factors that go into the optimization of inspection locations/components are the estimates of consequences obtained from probabilistic safety assessments (PSA) and the pipe failure probabilities.

In 1994, the Swedish Nuclear Power Inspectorate (SKI) established an R&D project known as the SKI-Pipe project, which developed a piping reliability analysis framework [1,2] and a pipe failure data collection.collected information on pipe failures into a database for the purpose of analysis. The project continued for four years until 1998, after which the data collection continued to be supported by an active maintenance and applications program.. In 2000 and based on the pipe failure data collection that had resulted from the SKI-Pipe project, certain member countries of the Nuclear Energy Agency (NEA) and the Organization for Economic Cooperation and Development (OECD) decided to establish the OECD Piping Failure Data Exchange (OPDE) Project. (OPDE) which, similarly to the SKI-Pipe project, would consist of a database collecting piping failu re reports for the purpose of analysis and multi-lateral co-operation in piping failures. The initial phase of the OPDE Project beganins officially in 2002 and it will continues until 2005. The project's Phase 1 involves validation of data records for the time period 1999-2001first phase of the project will collect piping failure data dating from 1970 to 2002. From 2003 and onwards, the project participants will continue to validate database records and expand the time period to 1970-2003.

Purpose of the OPDE database

Objectives of the OPDE Project include the establishment of a framework for multi-national cooperation in piping reliability. Initially a three-year program (2002 – 2005), the primary activities of the OPDE Project are to [3]:

- Collect and analyze pipe failure data in order to promote: a better understanding of underlying causes of failure, observed and potential impact on plant operation, safety and prevention. Project participants that provide validated pipe failure data will gain full access to the OPDE database.
- Generate qualitative insights about the root causes of pipe failures.
- Establish a mechanism for efficient feedback of experience gained in connection with pipe failure and development of defenses against pipe failure.

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- Collect information on piping reliability attributes and influence factors to facilitate estimation of pipe failure frequencies.

The goals of the OPDE database have expanded significantly since the creation of the initial database in 1994. The database on which the OPDE project is based was designed for multiple activities such as, and although its current goals could be subject to expansion in the future, revision 0 of the database supports the following items:

- Trend analysis, including aging analysis.
- Statistical analyses to determine pipe leak and rupture frequencies.
- Source of data parameters for input to probabilistic fracture mechanics codes.
- Basis for developing defences against recurring (e.g., systematic) pipe failures.
- Basis for exchange of service data in order to pinpoint potential generic implications of specific, significant pipe failure.
- Basis for degradation mechanism analysis (DMA) in risk-informed in-service inspection program development.

With such goals in mind, the question was raised as to what kind of events would qualify as acceptable information to be stored in the database. The database's current scope includes the following events [4]:

- any non-through wall defects such as cracks or wall thinning that exceed the design code, or are significant;
- small leaks such as pin-holes, leaks, drop-leaking which result in piping repair or replacement;
- large leaks including any ruptures;
- any severances (i.e., pressure boundary failure due to external impact).

An event classified as a *crack* implies that the crack tip did not penetrate the pipe wall. *Pinhole leaks* are defined as cracks of limited width and length penetrating the pipe wall leading to visible water seepage of drop leakage. Events involving at-power leaks discovered through normal global or visual leak detection systems are classified as *leaks*.

The term *rupture* refers to a sudden, major piping failure having a significant effect on plant operations. The leak frequencies are classified according to the system group, pipe dimension and expected degradation mechanism (e.g., reactor coolant system, DN 300, Stress Corrosion Cracking).

Parties Involved in the Project

At the outset of the OPDE project, the Currently, the database containeds a total of approximately four thousand four hundred records from all member countries[3], of these about eight records were from Canadian plants.which eighty-two have been provided from Canada. The structure of the process for which data is acquired and validated involves several key stakeholders for each participating country, mainly: the OPDE Clearinghouse (CH), the regulator, in Canada's case, the Canadian Nuclear Safety Commission (CNSC) and the licensees.

The OPDE project has put a lot of emphasizess on quality and validity of data validity, and therefore for this reason, each record must be appropriately reviewed and subsequently validated by all concerned parties before being eligible for its use in the database. The national coordinator of the respective participating country is responsible for data submissions according to a protocol defined in the OPDE Coding Guidelines [4]. The clearinghouse on the other hand, is responsible for maintaining the database, including verifying that the data submissions are in compliance with the Coding Guidelines and the Quality Assurance program that have been established for the project [4].The clearinghouse is responsible for obtaining failure reports, and then deciding which reports will be eligible for validation. This is a preliminary screening process to ensure that only the events that are within the scope of the project guidelines will be used. Once the necessary reports are acquired for all piping failure incidents, the clearinghouse extracts the necessary information for the database fields, and subsequently creates the appropriate records for the database.

The CNSC's role in the project necessitates achieving two main goals. The first is to review existing the records for any errors or discrepancies and to complete any information that may be missing. The second an equally important role, is to encourage licensees to participate in the project. Since the licensees are not directly involved in the project, they have no obligations to participate in it. The involvement of licensees is important as they are the ones that have the most in-depth knowledge of significant events, as well as extended access to non-public sources of information. The records from the database will then be submitted to participating licensees for review. Once reviewed, licensees would re-submit them to the CNSC, which would subsequently forward the validated records back to the clearinghouse for insertion into the main database. To date, most Canadian licensees have agreed to participate and this high level of licensee cooperation is very welcomed by the CNSC staff.

The OPDE project consists of an international database of piping failure records, therefore strong organization and coordination between the participating countries is necessary for the success of the project. The cclearinghouse has a key role to play within the coordinating process. Throughout the course of the project, the database structure including database field definitions, have been harmonized according to international piping reliability and structural integrity practices and codes. As examples, the new OPDE database includes cross reference tables for piping material designations and piping classifications, between different national codes. Although the OPDE database is based on the original SKI-Pipe database, several modifications to the structure of the database have been implemented in order for it to be of

3 Member countries participating in the OPDE project consist of Canada, Belgium, Switzerland, Germany, Spain, Finland, France, Japan, Czech Republic, Korea, Sweden and the United States, as of summer 2003.

international interest. One element that the clearinghouse needed to standardize was the measuring units to be used in the data fields. This is especially important if the values of the data fields were to be used as a search criterion for retrieving records. Another key element that needed to be coordinated was the data fields which would compose the database. Although the SKI-Pipe project had established appropriate data fields, the OPDE project expanded the purposes of the original project, which called for the creation of additional fields.

Project Phases within the CNSC

At the start of the project (May 2002), the OPDE database included over 4,400 records on pipe degradations and failures in commercial nuclear power plants worldwide. Table 1 shows the database content as of May 2003. This data collection currently represents a combined total of about 7,500 reactor-years of operating experience.

Table 1: OPDE Database Content (May 2003)

Pipe Diameter	No. of Database Records			
	Cracks	Leaks	Ruptures	Pressure Boundary Challenge
≤ DN 50	135	1625	142	11
> DN 50	1203	1092	108	345
TOTALS	1338	2717	230	356

In the OPDE database, each record corresponds to a case history with a complete and unambiguous description of an event. For each record, there are five types of data groups:

- Plant Data
- Piping Design & Fabrication Data
- Service Condition Data
- Inspection Data
- Event Data

Upon receiving the database records (which are in the form of a Microsoft Access table or spreadsheet) from the clearinghouse, all records were reviewed for completeness. Once this task was completed the next step involved research, mainly to find the appropriate references in order to conduct an efficient review. Although in some cases, the database listed appropriate references containing all necessary information, in many other cases the references given contained only fragments of the original licensee's report of the event. Whenever possible, the licensees' reports were used along with Incident Reporting System (IRS) reports which were considered to be the most accurate source of information.

Potential problems in tracing the references for some database records due to archiving and storage policies of older reports may arise throughout the process of validating older database entries. This could result in some records being inaccurately reviewed. The quantity of technical information residing in older reports may also prove to be insufficient in providing a complete verification of all data fields in each record. The overall consequence of a lack of appropriate documentation could undoubtedly result in a lowered quality of the records within the database. To compensate for such problems, a Quality Index has been attributed to every record, which in effect indicates how complete a record is. The index is based on a scale varying from 1 to 6, the lower the QA index, the better the record. By looking at these indices, a tendency that the reports' QA indexes increase with their age can clearly be observed. *(See Figure 1.)*

With such a tendency, which intuitively would have been expected since the beginning, one would think that older reports would not be used in the database at all or at the most, used sparingly. However, and perhaps surprisingly out of eighty-two Canadian records fifty (61%) of these were found to have QA indices of 4 or above and 59 (72 %) of all records date back prior to 1984.

The usefulness and value of using a large number of reports that may be considered "outdated" from the database might seem questionable. It would appear to contradict the database's purpose of utilizing records for the exchange of information. However the database, although still in its early phases, also serves as a basis for statistical analysis in determining leak probability for specific locations within the plant and rupture frequencies. Given the recentness of the project, very few records of pipe failures would have been available if the guidelines would have excluded the use of records dating prior to the mid-eighties. This would have reduced the statistical analysis value of the database. This also underscores the importance of spanning the project over a three-year period. It will expand the collection of recent records, therefore increasing the percentage of higher quality records within the database.

The records provided by the clearinghouse to the CNSC for reviewing come from six different power stations. The distribution of these records is unevenly divided, with most records originating from Pickering A. The exact distribution of the records from all stations is given in *Figure 2.*

The initial disproportionate distribution of records is not expected to affect the licensees' interest in project participation or have any impact on the project. This imbalance is expected to dissolve as new records are added from participating licensees in the subsequent phases of the project. The effectiveness of reviewing a record is a function of the completeness of a report. Due to the fact that data is collected from piping failures that have been occurring over a considerable period of time, several different types of reports were used in the reviewing process. Consequentially, depending on the format and content of the report, the overall data from the records was verified with varying degrees of accuracy.

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Benefits from the Project

Several benefits ensue from the project. Statistical knowledge of certain pipe failure causes may provide grounds for design optimization. Conversely, the approval of new designs for pipes and fittings may be facilitated if statistical information from other countries/ facilities with similar designs shows that they meet safety requirements. The process of optimization may also be accelerated as the comparison of technical information on specific components may give indications as to which types of fittings and pipes (i.e., dimensions, material, and type of weld) work best. It follows that these advantages lower the cost and time required to develop and implement improvements for all types of pipes and fittings, which ultimately benefit the licensee. At the international level, these advantages are still quite present. Since many of the participating countries have developed their own reactors, the failure rate of various components may vary from one country to the next. Data comparison between members provides an excellent opportunity for improvements and optimization in such cases.

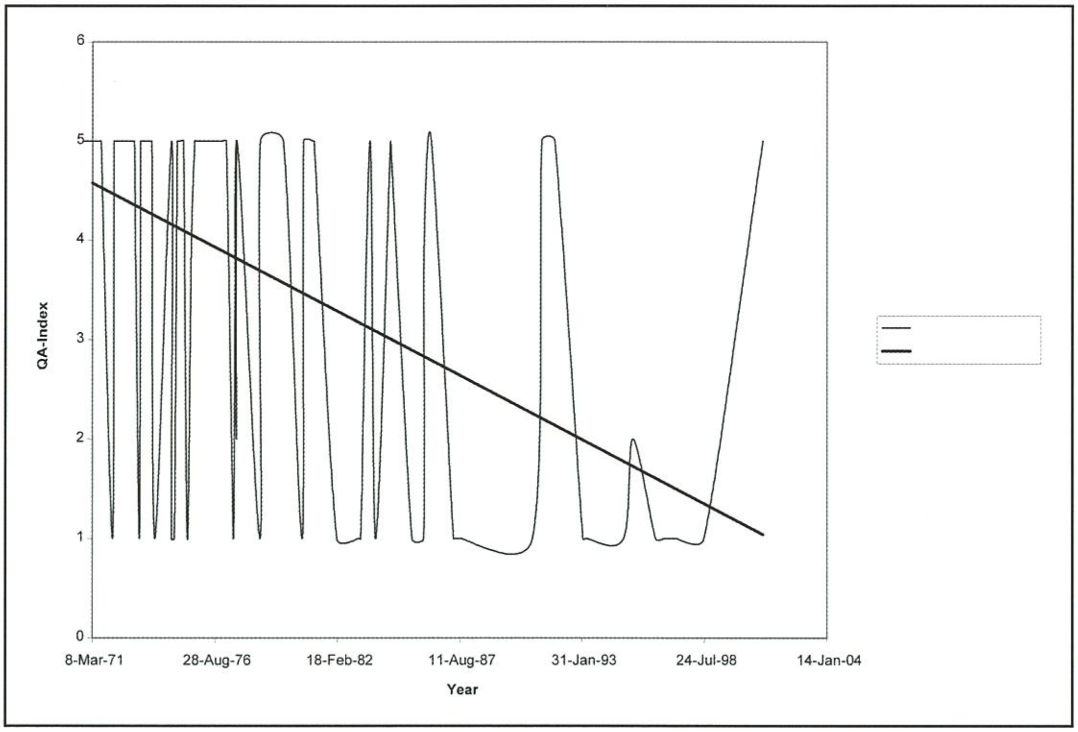

Figure 1: QA Index versus Time

The database also provides insight for reactor designs, by indicating if they might be subject to premature aging due to several factors such as thermal fatigue, flow assisted corrosion, stress corrosion cracking, or pump-induced vibrations. Premature aging does not include water hammer unless it has resulted in pressure boundary degradation or pipe failure. Such insight in maintenance related parameters could enable the utilities to prevent many piping failures, as well as increase/decrease the frequency of the inspections of components needed since they would have a better statistical knowledge of their time to failure as well as other technical data.

Lydell [53] used the database to estimate the frequencies of leaks and ruptures in medium and large diameter reactor coolant pressure boundary piping at Barseback-1 nuclear power plant. In Barseback-1, important contributions to the LOCA frequencies from pipe defects are due to thermal fatigue. Other significant LOCA frequency contributions are due to trans-granular and inter-granular stress corrosion cracking in the base metal bends of cold worked medium diameter piping. Compared with the seminal Wash -1400 study, the new medium and large LOCA frequencies for Barseback-1 were lowered by about one order of magnitude.

Recently, Simola et al., [64] used the insights and results from the SKI-Pipe project to make a comparison of database to estimated pipe leaks and rupture frequencies based on probabilistic fracture mechanics and statistical analysis of service data. Using for stainless steel piping in BWR reactors and to compare statistical estimations against probabilistic fracture mechanic models. Based on the results from this comparative study, the authors developed a methodology for estimation of LOCA frequencies and pipe degradation evaluation for RI-ISI applications at nuclear power plants in Finland.

Additional database applications include:

- Internal flooding probabilistic safety assessment (PSA); the database has supported the development of plant-specific internal flooding initiating event frequencies associated with fire protection piping and service water piping failure;
- Degradation mechanism evaluation in support of risk-informed ISI program development for U.S. plants (Byron, Braidwood, Dresden, Quad Cities, Clinton, LaSalle, Peach Bottom, Susquehanna and Three Mile Island);
- Surveys of piping performance in Soviet designed reactors (RBMK and VVER);
- Reliability assessment of a BWR reactor water level indication instrument line arrangement;
- Helium pressure boundary reliability assessment in support of the PBMR conceptual design.

Conclusion

The OECD Pipe Failure Ddata Eexchange project has received a considerable amount of international interest and since its debut in 1994.With new countries joining into the on a frequent basis, the project now counts twelve eleven members. Although the project is only in its initial stages of development, the improvements that have been implemented over the last year are numerous. Data from the database has already been used for practical applications on nuclear power plants in support of risk-informed in-service inspections or for estimating LOCA frequencies from piping defects. As the research project evolves into a fully functional and continuously maintained database, its benefits and ensuing success will be a stepping-stone for multi-lateral cooperation on new research and information sharing projects. Such projects provide excellent framework for the growth and improvement in the nuclear industry. However, the project will only be successful with the continuing support from all licensees. The project provides an effective tool and technical basis in support of the development of such items as risk-informed in-service inspection programs for Canadian licensees, probabilistic safety assessment (PSA) initiating event frequencies associated with piping system failures, degradation mechanism evaluation, reliability assessment of instrumentation systems as well as several other examples.

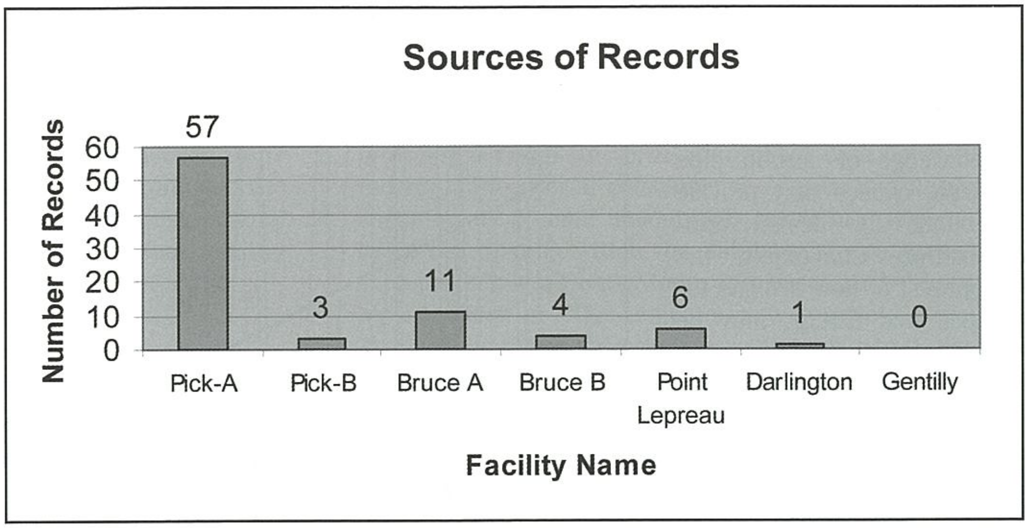

Figure 2: Distribution of records of Canadian plants as of 1999.

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GENERAL news

Ed. Note: *The following items are derived from a number of reliable sources but their accuracy is not guaranteed.*

Bruce Power responds quickly after blackout

Bruce Power responded to Ontario's power needs following the major loss-of-grid incident that blacked out most of the province and parts of the United States August 14, 2003.

Three of the four units at the Bruce B generating station were put in standby mode and, within hours of the incident, were reconnected to the provincial grid. All of the station's standby systems worked as designed when the loss-of-grid incident occurred. As a result of the disruption, unit 6 did shut down but was returned to service later. Together, units 5, 7 and 8 have 2,400 MW of electricity available when called upon by the Independent Market Operator (IMO).

One unit of Ontario Power Generations Darlington station was put into standby. The remaining three at Darlington and all four of the Pickering B station shut down and poisoned out.

MDS Nordion, which runs a very time sensitive production line for the short half-life molybdenum 99, relied on its back-up generators to maintain the flow of this widely used medical diagnostic isotope.

McMaster hosts TRTR 2003

McMaster University, specifically the McMaster Institute of Applied Science (McIARS), which operates the McMaster Nuclear Reactor, hosted the 2003 conference of the National Organization of Test, Research and Training Reactor (TRTR), in Hamilton, Ontario, August 12-15, 2003.

The conference, which was held in the downtown Sheraton Hotel, drew delegates from six continents. They were greeted at the pre-opening reception, August 12, by Dr. Mamdouh Shourki, vice-president, research and international affairs and Dr. David Chettle, Director of McIARS. The conference began officially August 13 with an address by the President and Vice-Chancellor of McMaster, Dr. Peter George. The next day, August 14, began with Linda Keen, president of the Canadian Nuclear Safety Commission, speaking about regulatory aspects, and ended up with a "gala" at the Royal Botanical Gardens, in the dark, because of the large power failure that afternoon

TRTR represents reactor facilities from government, universities, national laboratories and industry. Begun as a small technical group in the sixties, TRTR quickly grew into a national and now international organization and adopted its current name in 1976. TRTR's primary mission is education, fundamental and applied research, application of technology in areas of national concern. The organization holds annual conferences to discuss current technical and regulatory issues, advances in research and education, operating experience, and development of new applications in medicine, materials, health and safety, information technology, and environmental sciences.

The McMaster Nuclear Reactor (MNR) began operating in 1959 as the first university based research reactor in the British Commonwealth. It is a pool-type reactor, with a core of enriched uranium fuel moderated and cooled by light water. It operates weekdays from 8 a.m. to 12 midnight at a thermal power of 2 MW. MNR has been upgraded to operate at powers up to 5 MW, with a maximum thermal flux of 1 x 1014 neutrons/cm2 per second. Plans are in the works to convert to Low Enriched Uranium fuel to ensure continued safe operation and comply with international standards.

CAE modernizes Cernavoda simulator

Montreal based electronics and software company CAE has been awarded a contract by Nuclearelectrica SA of Romania to update and modernize the plant simulator for its Cernavoda 1 CANDU 6 nuclear power plant, which started operation in 1996.

CAE will provide new instructor stations, replace the simulator's VAX 4500 computers with Linux-based PC servers and replace a large number of the existing simulation models with high fidelity versions. As well the reactor core model will be replaced with a higher fidelity one called COMET.

In addition the Unit 1 simulator's Digital Control Computer (DCC) will be replaced by a software-based emulation. The original DCC, a fully functional plant control unit developed by CAE a decade ago, will be kept as a back-up for the Unit 1 reactor control.

CAE has also been contracted, through Atomic Energy of Canada Limited, to provide an updated DCC for Cernavoda 2, which is now under construction.

This year CAE is celebrating its 30th anniversary of making nuclear power plant simulators. The first was for the Pickering A station in 1973. Since then CAE has supplied simulators for all CANDU stations throughout the world. From that experience CAE evolved into the major supplier of simulators for light water rectors as well.

AECL completes dry storage facility in Romania

Also in Romania, on July 28, 2003 the Honourable Don Boudria, Minister of State and Leader of the Government in the House of Commons, participated in the official opening of the MACSTOR spent fuel storage facility at the Cernavoda nuclear power plant site, along with representatives of Atomic Energy of Canada Limited, Romania's Societatea Nationala Nuclearelectrica and the Romanian government.

The facility was built with the participation of Nuclearmontaj of Romania. The MACSTOR dry fuel storage facility is designed by and its proven technology is already in use in Canada at several nuclear plants.

Used fuel is initially stored in spent fuel bays at the reactor sites. After several years of cooling in the bay the fuel rods can be moved to a MACSTOR facility where they can be safely stored for decades. MACSTOR dry spent fuel storage facilities are designed for more than fifty years of on site operation. The Romanian facility will be monitored by the International Atomic Energy Agency.

Qinshan 2 in commercial service

The second CANDU unit at the Qinshan III site in China officially went into commercial service on July 24, 2003, four months ahead of schedule, joining Unit 1, which was declared in service on December 31, 2002, also ahead of schedule.

Ken Petrunik, vice-president of projects at Atomic Energy of Canada Limited, and director of the Qinshan project received a letter from Prime Minister Chrétien congratulating him and his team. Petrunik also recently received a People's Republic Friendship Medal from the government of China.

AECL has also announced the opening of the *CANDU Engineering Centre (CEC)* in the People's Republic of China. The centre will provide a useful resource base supporting the development of the Advanced CANDU Reactor (ACR) and its commercialization in China.

AECL is supporting the Centre's first year of operation. Eight Chinese technical staff from the Shanghai Nuclear Engineering Research and Design Institute will undertake a variety of assignments relating to safety thermalhydraulics, reactor physics, modules and integration, process, and reactor and fuel handling.

The *CANDU Engineering Centre* is located on the main engineering campus of the Shanghai Nuclear Engineering Research and Design Institute in Shanghai.

McArthur River mine back in production

Cameco Corporation announced in early July that the McArthur River mine was back in production. This was about a month earlier than previously anticipated.

Production had been suspended since April 6, 2003 when additional water began to flow into the mine. McArthur River personnel began mining underground with two raisebore machines on June 30 and had a third unit functioning in early July, bringing mining operations up to full capacity. McArthur River ore is processed at the Key Lake mill, which restarted on July 1.

The additional water inflow at the McArthur River mine is stable and being drained through a series of pipes from the affected area to an inactive part of the mine before being pumped to the surface. The water continues to be treated and monitored to ensure good quality. The area where the water entered the mine has been filled with concrete and was expected to be permanently sealed off by mid-August.

Cameco expects the McArthur River / Key Lake operations will produce approximately 12 to 13 million pounds of uranium in 2003 (Cameco's share about 8 to 9 million pounds) compared to the annual licensed capacity of 18.7 million pounds.

President of AECL Technologies appointed

Atomic Energy of Canada Limited has appointed John Polcyn as president of its subsidiary AECL Technologies Inc. located in Gaithersburg, Maryland, USA. His primary role and that of the subsidiary is to market the ACR 700 in the USA.

Polcyn was formerly vice-president of marketing at Bechtel Power Corporation, AECL's partner in the ACR 700 project for conventional systems.

The ACR 700 is currently going through pre-application review with the US Nuclear Regulatory Commission. The design has been included in the Early Site Permitting process of three participating US utilities.

Japan to pursue MOX

The Atomic Energy Commission (AEC) has released a nuclear energy policy blueprint, which calls for continued pursuit of the mixed-oxide (MOX) fuel program and the restart of the Monju fast-breeder reactor (FBR). The commission - which operates under the Cabinet Office - is conducting a review of Japan's nuclear energy policy following the plant data falsification issues uncovered in 2002. The blueprint is designed to serve as a basis for a long-term nuclear energy plan to be published by the government in 2004.

MIT study supports nuclear

The Massachusetts Institute of Technology (MIT) has published an interdisciplinary study that examines the prospects and challenges faced by the nuclear power industry, focused on the USA.

The study states that the nuclear option must be retained "precisely because it is an important CO2-free source of power". The authors urge the US to focus its attention over the next decade on building nuclear reactors that use existing technology and a 'once-through' fuel cycle.

The study postulated a 'grow scenario' by 2050 of about 700 new reactors worldwide, each of approximately 1000 MWe of capacity, to keep nuclear's share of the electricity market constant. However, for a large expansion of nuclear energy to take place, four critical areas must be addressed: better economics; continued high security; waste management; and, proliferation issues. The report - "The Future of Nuclear Power" - is available at < http://web.mit.edu/nuclearpower >.

MDS Nordion licenses Y-90 technology

MDS Nordion is licensing technology to NTP Radioisotopes (Pty) Ltd., a subsidiary of the South African Nuclear Energy Corporation (Necsa Ltd.) that will see NTP become a contract supplier to MDS Nordion of yttrium-90, an important medical isotope used in ground-breaking radioimmunotherapies to treat cancer. NTP has also been licensed to use MDS Nordion's Y-90 production technology to produce and market Y-90 under its own brand in countries outside of Europe and North America.

NTP is based at the large Pelindaba nuclear site near Pretoria in South Africa. It produces and markets a range of quality radiochemicals, radiopharmaceuticals and various associated products and services for customers in healthcare, life science and industrial markets in over 40 countries on five continents.

MDS Nordion's Y-90 generators in Fleurus, Belgium, already constitute the largest Y-90 production capacity in the world. This new partnership will create an additional source of supply to MDS Nordion of Y-90 radiochemical for processing into Y-90 radiopharmaceuticals used to manufacture cancer drugs such as IDEC Pharmaceuticals Corp.'s Zevalin (TM). Zevalin is the world's first approved radioimmunotherapy and is used to treat a form of non-Hodgkin's lymphoma.

Radioimmunotherapy is a promising new area of cancer treatment that combines the targeting power of monoclonal antibodies with the cell-damaging ability of localized radiation. Radioimmunotherapies like Zevalin are enabled by linking monoclonal antibodies to radioactive isotopes. The antibodies are specially engineered to recognize and attach to specific targets on the surface of certain cancer cells. When infused into a patient, these radiation-carrying antibodies circulate in the body until they locate and bind to the surface of the targeted cells where they deliver their cytotoxic radiation to destroy the malignant cells.

MDS Nordion supplies the medical isotope used in Zevalin, and manufactures a finished iodine-131 radioimmunotherapy product, Bexxar (TM), for Corixa Corp. Zevalin and Bexxar are the only radioimmunotherapy products currently approved by the US Food and Drug Administration. MDS Nordion will integrate Y-90 radiochemical supplied by NTP into its routine production schedule for sterile Y-90 radiopharmaceutical over the coming months.

NWMO needs your comments

The Nuclear Waste Management Organization is seeking comments on its program and on the general question of the management of spent fuel from nuclear power plants.

The NWMO has established an active website < www.nwmo.ca > on which they have posted their first annual report, their "study plan", and, in the context of obtaining opinion, an "engagement plan".

This is an excellent opportunity for individual members of the Canadian Nuclear Society and others concerned about appropriate development of nuclear power in Canada to express their views. Over the past winter and spring the NWMO conducted a number of "focus groups" and found (not surprisingly) that most people had little knowledge of nuclear power let alone the question of "nuclear waste" but were apprehensive. Credible, positive comments could help the NWMO develop a practical and acceptable plan for the long-time management of spent fuel from our nuclear power plants.

One person who has been active in this matter is Archie Robertson, retired senior researcher at AECL's Chalk River Laboratories. He has produced a new essay on the "ethics" of nuclear fuel wastes which he has posted on his personal website < www.magma.ca/~jalrober >.

CNS news

Meet the President

He may be the youngest president of the Canadian Nuclear Society but Jeremy Whitlock brings many attributes to the position.

Although he claims to be an arch-typical Canadian, Jeremy was actually born in England, in Chipping, Sudbury, on September 15, 1965. (He claims that he was born in the same cottage hospital and the same year as author J. K. Rowling but complains that his career path has been less lucrative than hers.) However, the next year, his father decided to emigrate to Canada, initially to work at Canadair, but, shortly after, at the Chalk River Laboratories of Atomic Energy of Canada Limited (CRL). That led the family to move to Petawawa where Jeremy was initiated into an activity that became a passion -canoeing.

While still a young teenager he joined the Petawawa Legion Band as a charter member and learned to play the clarinet. Later he became (and continues as) Assistant Conductor and a teacher in the Band School.

Becoming interested in what was going on at CRL (or, perhaps, just looking for a summer job) after graduating from high school he spent the summer of 1984 as a "decontamination operator" which he describes was really the lowest of janitorial work. Nevertheless his interest in nuclear science had been piqued and he enrolled in the engineering physics program at the University of Waterloo. The following summer he was back at CRL as a technical assistant in the Tandem Superconducting Cyclotron (TASCC) facility.

He spent two more summers at CRL in 1987 and 1988 before enrolling in graduate school at McMaster University. There he studied reactor physics under Prof. Bill Garland, a very active member of the CNS whom Jeremy credits for his initial interest in the Society. After receiving a M.Eng. in 1991 he continued at "Mac" where he obtained a Ph.D. in 1995. His doctoral thesis was "Reduction of the Positive Void Effect in a CANDU Lattice Cell". During the last year of his doctoral studies he worked at AECL's Sheridan Park office in the Reactor Core Physics Branch. Since that branch is managed by Ben Rouben, a past-president of the CNS, he was exposed to more of the activities of the Society.

Along the way, Jeremy took time to get married, in May 1989. His wife Beth followed him around during his graduate studies at McMaster and time at Sheridan Park before he joined the Canadian Neutron Facility project at CRL in late 1995. They moved to Deep River where they live with their three children, Alex, 8; Lucy, 6; and Evan, 2. (Jeremy now works on the MAPLE project.)

As well as canoeing and the Petawawa band Jeremy has been an active member of the Deep River Players and has appeared in several of their productions.

Somewhere along the way Jeremy became very interested in communicating the benefits of nuclear science and technology to the general public. That led him to create his own website in 1996 focussed on "Frequently Asked Questions" <www.nuclearfaq.ca> which has proven quite popular. For that effort and other related activities he was presented with the CNS Education and Communication Award in 1999.

The summer of 2002 saw the culmination of over two years of effort by Jeremy when an Ontario "Historic Plaque" was unveiled to recognize NPD, the first nuclear power plant in Canada.

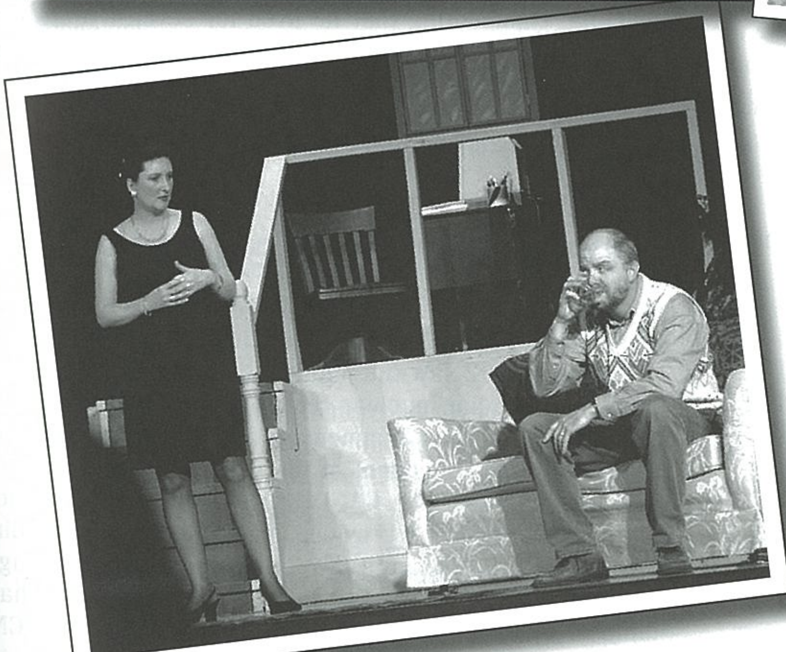
During his presidency Jeremy hopes to make the CNS more relevant to younger members of the nuclear community. He intends to use his ex-officio membership on the Board of the Canadian Nuclear Association to seek active and open support of the CNS by the CEOs of the member companies of the CNA. In that context he acknowledges the great support he receives from Peter Boczar, the Director of his division at AECL. To attract members and rejuvenate CNS Branches Jeremy hopes to enlist some "high profile" speakers to visit the branches, and would, himself, like to visit as many branches as possible during his tenure.

Reflecting his interest in communication and education he hopes to strengthen and expand the CNS support for programs in schools, teachers'courses, and journalism workshops.

To accomplish all of this on top of the demands of his job, of being a conscientious parent, and an active member of his community will obviously be a challenge. Fortunately, Jeremy appears to be blessed with considerable energy. He reports that he gets by with 6 1/2 hours sleep, typically retiring at midnight and rising at 6:30.

Even with that energy and enthusiasm he will need the full support of the members of the CNS to achieve his challenging objectives for the Society.

Clockwise from top left:
Jeremy at about the age of two (note the hair); with wife Beth and children (T to B) Lucy, Alex, Evan; a thoughtful pose of a couple of years ago; with Alex and Lucy beside the just erected NPD Historic Plaque, summer 2002; a scene from a Deep River Players production, "Jake's Women" with Alison McIver; dressed as a voyogeur at the time of AECL's Open House, summer 2000.



CNS Annual General Meeting

The sixth Annual General Meeting of Canadian Nuclear Society Inc. was held at the Marriott Eaton Centre Hotel in Toronto, Ontario, on June 9, 2003, at the end of the first day of the 24th CNS Annual Conference. It was recorded that 67 members attended.

Following the pattern of recent years the meeting began with the acceptance of the minutes of the previous AGM followed by an introduction of the Executive by president Ian Wilson and his review of the past year. *(See his report elsewhere in this issue.)*

In his report Ian Wilson noted that the Student Conference has been integrated with the Annual Conference program this year and encouraged members to attend the student sessions. He commented that, as of Monday afternoon, there were 298 registrants at the 2003 Annual Conference. *(The President's report is reprinted below.)*

Treasurer Walter Thompson presented his report for 2002 and tabled the report from the Auditor. He noted that due to its large surplus from previous years, the CNS had budgeted for an operating deficit of $35,200 in 2002. The actual operating deficit, as reported in the Auditor's Report, was $29,285. In addition, the CNS expended $30,847 from the Special Projects Fund during 2002 based on commitments made during 2001. (S.P. Fund expenditures were nil in 2001.) As a result, the overall operating deficit in 2002 was $60,132. *(Note that although the term of the Council is from AGM to AGM, the CNS operates financially on the calendar year.)*

In response to a question from the members, Thompson reported that the CNS has budgeted for a smaller deficit of about $15k in 2003. He stated that the outcome would be determined by the number and success of large conferences.

David W. Rogers was appointed auditor for CNS/SNC Inc. for the year 2003.

Brief reports were presented by the chairs of the various divisions and committees. Bill Schneider, chair of the Program committee noted that the Events Calendar had been mailed with the previous issue of the *CNS Bulletin* and was kept up to date on the CNS website.

Jeremy Whitlock introduced Branch chairs or representatives present at the AGM.

Bruce	E. Williams
Chalk River	Michael Stephens
Manitoba	J.W. for Jason Martino
New Brunswick	Mark McIntyre
Ottawa	Robert Dixon
Pickering	Jerry Cuttler for Mark Paiment
Québec	Michel Rhéaume
Toronto	S.Y. (Andrew) Lee
Sheridan Park	Parviz Gulshani

Ed Price, chairman of the combined CNS / CNA Honours and Awards Committee, reported that the Awards ceremony would be held at the Tuesday night banquet of the Annual Conference, and the CNA International Award presented at the Wednesday luncheon.

In reporting for the Internet Committee, Jeremy Whitlock noted that Morgan Brown had taken over as the new webmaster of the CNS website and has consequently assumed the position as Chair of the Committee.

Ben Rouben, chair of the Membership Committee reported that membership in the CNS has continued to increase year over year.

Mark McIntyre reported on the activities of the North America Young Generation Network (NAYGN) and invited members to attend the NAYGN professional development session and lunch on Tuesday. He presented an update on the preparations for the IYNC meeting in Toronto, May 2004.

Election and Installation of the New Council

Past President, Dave Jackson, as Chair of the Nominating Committee, proposed a slate of candidates. In response to a call for further nominations, Joseph Yeremian and Jad Popovic were nominated and seconded as members at large. Following a motion that nominations be closed the slate of candidates was elected by acclamation. *(See below)*

The outgoing President, Ian Wilson, presented an inscribed gavel to the incoming President Jeremy Whitlock and turned chairmanship of the meeting over to him. Jeremy Whitlock presented a plaque to Ian Wilson, in recognition of his leadership in the successful pursuit of Society objectives during his term as 22nd President.

Incoming president, Jeremy Whitlock, addressed the meeting, commenting that he lived for several years next door to the first President of the CNS, the late George Howey. He looks forward to exploiting opportunities for the Branches to share guest speakers and invited industry members to commit support to the IYNC meeting in 2004.

President's Report

By Ian Wilson

The year 2002 saw the publication and launch of a new book on Canadian nuclear technology entitled *Unlocking the Atom.* Dr. Hans Tammemagi and Dr. David Jackson, immediate Past-President of the CNS, wrote this book. It not only discusses the CANDU fuel cycle in easily understandable language; it provides an excellent understanding of radiation. It also puts the long-term risks in management of nuclear fuel waste in perspective with the handling of other wastes generated in our society. The CNS believes that this book deserves wide dissemination within the education field. CNS therefore paid to have a copy of the book placed in the libraries of every university in Canada. We commend it for much wider distribution and use.

Other education and communications activities which continued in 2002 included the funding of teachers courses on nuclear energy, journalist workshops on scientific reporting, attendance at the Deep River Science Academy, and providing prizes for science fairs and other special events.

A new CNS Newsletter named "C-News" was launched early in the 2002. It contains brief news items and notices of upcoming conferences and courses. It is circulated to an audience that goes well beyond CNS members by reaching out to a large group of non-members who attend our conferences and meetings. It therefore complements the existing excellent CNS Bulletin, which we continue to publish quarterly.

Also launched in 2002 was an Ask an Expert program. A large number of business cards were printed and disseminated providing web site addresses for a number of nuclear organizations including the CNS and CNA web sites. The cards also invite questions from the public on nuclear technology.

The CNS continues to organize successful and well-attended conferences and seminars on nuclear topics. In 2002 these included:

- Steam Generator Conference (May)
- Annual Conference (June)
- Simulation Symposium (Nov)
- Seminar on Radiation Effects on the Environment (Dec)

At the 2002 Annual Conference the CNS acknowledged and celebrated the 50th Anniversary of the founding of Atomic Energy of Canada Limited and the 40th Anniversary of first CANDU generated electricity at the NPD reactor at Rolphton, Ontario, in June 1962. The Ontario Heritage Foundation agreed to a CNS proposal to place a historical plaque near the site of the NPD reactor and the plaque was unveiled at a very well attended ceremony the day before the start of last year's Annual Conference. The CNS has also prepared an explanatory display board that has been located adjacent to the plaque. The CNS was also advised that our application to have NPD recognized as an Historical Nuclear Landmark by the American Nuclear Society had been granted. The presentation of this prestigious plaque by the ANS President took place at lunchtime today June 9. Plans are well advanced for a 2003 Fuel Conference and for the 6th CNS International CANDU Maintenance Conference to be held in November 2003. Next year's Annual Conference will be held once again here at the Marriott Eaton Centre.

As announced last year, CNS courses are eligible for credits under the Engineering Institute of Canada professional development recognition system. Courses held in 2002 were:

CNS Council for 2003-2004

Executive Committee:

J.J. (Jeremy) Whitlock	AECL	President
W.G. (Bill) Schneider	Babcock & Wilcox	First Vice-President
J.W. (Walter) Thompson	Nuclear Safety Solutions	Second Vice-President
E.M. (Ed) Hinchley	Formerly AECL	Treasurer
B. (Ben) Rouben	AECL	Secretary
J.E. (Ian) Wilson	Formerly CNA/OPG	Past President

Council Members-at-Large:

1.	J.M. (Jerry) Cuttler	Cuttler & Associates Inc.
2.	M. (Mike) Gabbani	GE Nuclear
3.	R.S. (Ralph) Hart	R.S. Hart & Associates
4.	J. (Jim) Harvie	Formerly CNSC
5.	R L (Bob) Hemmings	Canatom NPM Inc.
6.	D.P. (David) Jackson	McMaster University
7.	V.S. (Krish) Krishnan	AECL
8.	S.Y. (Andrew) Lee	Formerly OPG
9.	M. (Marc) Léger	AECL
10.	J.C. (John) Luxat	Nuclear Safety Solutions
11.	K. (Kris) Mohan	AECL
12.	E.M. (Dorin) Nichita	AECL
13.	M.R. (Michel) Rhéaume	Hydro-Québec
14.	R. (Roman) Sejnoha	Formerly AECL
15.	K.L. (Ken) Smith	UNECAN News
16.	B.F. (Bryan) White	AECL
17.	E.L. (Eric) Williams	Bruce Power
18.	J. (Jad) Popovic	AECL
19.	J. (Joseph) Yeremian	Thermodyne Engineering Ltd.

Ex-officio Members of Council:

W. (Bill) Clarke, President and CEO, Canadian Nuclear Association

All Division, Committee, and Branch Chairs who are not elected as Members at Large

- Reactor Safety Course (April & September)
- Fuel Technology Course (Sept/Oct)

In addition, CNS regional Branches held a large number of seminars on topics of interest to their members.

At this Annual Conference the Student Conference has been fully integrated into the parallel technical sessions. This permitted us to hold our annual Officer's Seminar on Sunday afternoon. Among the topics discussed was a future vision for the Society. Incoming Council will have the task of considering any actions indicated from this discussion.

Finally, we are encouraged that membership in the CNS continues to grow slowly but steadily. There is also a growing interest among the membership in volunteering to serve on Council and assisting with planning of events such as the Annual Conference. On behalf of the CNS Council, I would like to acknowledge the dedicated volunteer effort of all of those members who contributed to the success of the CNS program. I would also like to thank our sister organization the CNA, the companies in the nuclear industry, and many individuals for their support of CNS activities in 2002 and 2003. We look forward to your continuing encouragement and support in the coming year. I have greatly enjoyed my year as President. It was an honour and privilege for which I thank you.

Retiring CNS president Ian Wilson (R) presents the traditional gavel to Jeremy Whitlock following his election as president for the 2003 - 2004 term at the CNS Annual General Meeting, Toronto, June 9, 2003

BRANCH ACTIVITIES

Bruce *(Eric Williams, chair)*

Wednesday 18 June 2003 - **Dr. David Torgerson,** of AECL spoke on the Advanced CANDU Reactor. Over 50 attended Dr. Torgerson's presentation.

Wednesday 2 July 2003 - **Dr. Murray Stewart,** ITER Canada Host Organization, addressed the Branch on the ITER Project, an update and project description.

A social hour with light refreshments preceded both presentations.

Chalk River *(Michael Stephens, chair)*

The CR Branch math awards we offer at Mackenzie High School were presented on June 16, and **Elizabeth Dowdeswell** of the Nuclear Waste Management Organization gave a public seminar on July 24.

New Brunswick *(Mark McIntyre, chair)*

On June 20, 2003 the NB Branch hosted **Dr. Bob Hemmings,** Vice President of Canatom NPM. The topic was "ITER: Cleaner Energy for our Planet". Bob described the growing ITER collaboration and the efforts to demonstrate the benefits of bringing ITER to Canada. It was encouraging to hear the commitments from the Ontario Government to share risk in the project, it is now the Canadian Federal Government's turn to commit to the project. It was revealed that the major weakness of Canada's offer to host ITER is the lack of Federal support.

The questions from the crowd assembled at Point Lepreau allowed Dr. Hemmings to describe the enormity of the project: from the sheer size of the facilities, to the super cooled magnets, to super high temperature plasma...fusion pushes the limits of today's science.

Ottawa *(Bob Dixon, chair)*

The Ottawa Branch notes the awarding of CNS Fellowship to Branch member **Ralph Green** at the CNS annual conference in June.

Sheridan Park *(Parviz Gulshani, chair)*

The Branch hosted **Dr. J. Marvin Herndon** on June 24th, speaking on the "Nuclear Heart of the Earth".

Toronto *(Adam McLean, chair)*

Dr. J. Marvin Herndon, Independent Researcher and Management Mining Consultant, San Diego, California, presented a seminar on "Nuclear Heart of the Earth" in the University of Toronto Wallberg Building on Tuesday, 2003 June 24.

The CNS Website: An On-Line Resource

by Morgan Brown

Providing technical information on nuclear science and technology is a major task of the Canadian Nuclear Society/ Société Nucléaire Canadienne. To help with this, our society has been operating a web site since 1998, located at < www.cns-snc.ca > . As your new Webmaster, I would like introduce you to some of the features of the site, and some of the plans for the future.

First, I wish to express my thanks to my predecessor, Jeremy Whitlock, for building up and maintaining the web site, and to the many contributors: including Peter Pfeiffer, Adam McLean, Gary Dyck, Ben Rouben, Jaro Franta and the late Peter Laughton (apologies to those I've missed).

The CNS/SNC web site begins with an opening page, where you can select either French or English. Most primary pages, and some sub-pages, are in both official languages to reflect the Society's national status. I'd like to see more of the pages translated into French - my own command of French is limited (but improving) and Ben Rouben and Jaro Franta have been most helpful with translations. Also, I'd like to see some pages developed for Francophone audiences - any takers?

There is a sidebar on the left hand side that connects to primary pages for (i) conferences and courses, (ii) news, (iii) an event calendar, (iv) the Bulletin, (v) education, (vi) publications, (vii) job listings, (viii) CNS member c.v.'s, (ix) CNS branches, (x) honours and awards, (xi) nuclear history, (xii) nuclear links, (xiii) the CNS Council, (xiv) membership, and (xv) how to contact the Society. Also on the sidebar are links to upcoming big events, notably conferences organized by the CNS.

The **Bulletin page** shows the contents of the latest issue of the Society's quarterly journal, with one or two links to articles. There is a table of contents for Bulletin back issues, presently going back to 1989; eventually I hope to extend the listing back to volume 1, number 1.

The **Conference and Courses page** includes a link to an index of CNS/SNC conferences, which lists all papers and authors from these conferences. While still incomplete, the index presently contains 55 conferences and almost 3000 papers. There are plans to convert the information into a database for improved searching. As with the Bulletin index, a few of the papers are available on-line.

The **Nuclear Links page** lists a large number of internal and external web resources on nuclear science and technology. The internal resources include a map of Canadian nuclear sites and reactor performance graphs; additional pages on fusion, renewable energy, the electricity market and other nuclear and energy topics are available on the CNS Toronto branch page, courtesy of Adam McLean.

The **Nuclear History page** concentrates on the Canadian perspective, including a chronology, pages on various nuclear "pioneers", reprints of articles, and links to other sources - such as the CANTEACH site with histories of the CANDU reactor and various CANDU systems. There are numerous articles and photographs commemorating the 40th anniversary of the first Canadian power reactor - NPD - celebrated in 2002. Could you write an article on your favourite Canadian nuclear pioneer?

The CNS/SNC web site also provides our membership with a **"members-only"** benefit, the ability to post your curriculum vitae on the web, free of charge. You can post it anonymously, if you wish - the instructions are on the c.v. page. We also provide a page to post jobs; potential employers should contact the CNS office for details. The job page also has links to the career and employment pages of several Canadian nuclear-related companies.

My description of our web site is by no means exhaustive - you should explore our web site yourself. There are many opportunities for you to improve the site, and make additions. You don't have to know HTML (the internet coding language), as we can do the necessary translations. And please let me know of any errors, omissions and dead links - I want our site to be useful, up-to-date, accurate, factual and trustworthy. Not only does the CNS/SNC web site provides information for our membership, but also acts as a reliable and informative public source on nuclear science and technology - past, present and future.

Draw Winners

To entice delegates to return their names badges at the end of the 24th CNS Annual Conference, held in Toronto, June 8 - 11, 2003, the organizers held a draw.

There were six prizes: two personalized Inukshuks; and four copies of the book "Canada Enters the Nuclear Age".

The winners were:

Inukshuk: Dave Duncan, (D.F.Duncan Ltd.) and Jad Popovic (AECL)

Books: Marc Desormeaux (RMC); Adriaan Buijs (AECL); Todd Mitton (RCM Technologies); Paul Ingham (AECL)

New members / Nouveau membres

We would like to welcome the following new members, who have joined the CNS recently.

Nous aimerions accueillir chaudement les nouveaux membres suivants, qui ont fait adhésion à la SNC récemment.

Neil Alexander, Atomic Energy of Canada Limited
Mario Deschênes, Polytechnique - McGill
Doug Brophy, AECL
Edwin R. Rivenbark, Neill & Gunter Limited
Jason D. Wagg, Babcock & Wilcox Canada
Dawn E.D. Wintour, Carleton University, Industrial Design
Andrew L. Muller, The Society of Energy Professionals
Wilhelm M. Postma, Mariner's Inn
Iain F. Wilson, Imaging & Sensing Technology
Steven Ford, AECL
Martin Pierre, Director General Nuclear Safety
Mike J. Nagy, RCM Technologies Canada Corp.
Edward E. Caton, Babcock & Wilcox Canada
José Freire-Canosa, Ontario Power Generation
Paul Busatta, Royal Military College
William C.H. Kupferschmidt, AECL
Chip Horton, General Physics Corporation
Selene Claire Ing, University of Toronto, Industrial Engineering
Paula Lum, Bruce Power
Sundar Raman
Yi-Feng Fan, Ecole Polytechnique

Message from the Membership Chair

Dear CNS member:

Automatic Membership Renewal

Our modern lifestyles are crowded with all kinds of activities. This explains why, at membership renewal time, a number of CNS members forget to return their renewal form promptly. As a result, they end up renewing late, at a higher fee, or, in the extreme, they even let their membership lapse. Don't let this happen to you. Why not subscribe to the automatic renewal option, as a good number of CNS members have already done? This is the easiest way to maintain your CNS membership up-to-date from year to year, and also take advantage of the lowest renewal fees. If you subscribe to automatic renewal, the CNS office will automatically renew your membership in late November or so on your credit card, at the 1-year or multiple-year rate, as you specify. If I have convinced you and you would like to subscribe, please fill out the attached form or simply communicate with the CNS office by phone or e-mail.

Help Us Keep the CNS Membership Database Up to Date

If any of your personal information (e.g., employer, title, address, phone number, e-mail address, etc...) has changed recently or will soon change, please send the correct information to the CNS office (numbers below) so that we may keep the membership database in good order. Thank you!

Message du président du comité des adhésions

Cher/Chère membre de la SNC

Renouvellement automatique d'adhésion

Notre mode de vie moderne est plein de toutes sortes d'activités. Ceci explique pourquoi un certain nombre de membres de la SNC oublient, au moment du renouvellement des adhésions, de renvoyer leur formulaire à temps. Ce qui veut dire qu'ils finissent par renouveler tard, à un taux plus élevé, ou encore, à l'extrême, de voir leur adhésion être éventuellement annulée. Ne laissez pas ceci vous arriver. Pourquoi ne pas simplement cous inscrire au renouvellement automatique, tel que bon nombre de membres l'ont déjà fait? C'est le moyen le plus facile de vous assurer que votre adhésion à la SNC demeurera en bonne et due forme d'année en année, tout en profitant toujours des taux de renouvellement les plus bas. Si vous vous inscrivez au renouvellement automatique, le bureau de la SNC renouvellera automatiquement votre adhésion vers la fin de novembre ou le début de décembre sur votre carte de crédit, au taux d'un an ou plus, comme vous le préférez. Si je vous ai convaincu, veuillez remplir le formulaire ci-joint, ou bien simplement communiquer avec le bureau de la SNC par téléphone ou courriel.

Veuillez nous aider à garder la banque de données des adhésions à jour

Si tout détail personnel (par exemple employeur, titre, numéro de téléphone, adresse électronique, etc...) a changé récemment ou changera très bientôt, veuillez le communiquer au bureau de la SNC (numéros ci-bas), afin que la banque de données soit toujours correcte. Merci bien !

Tel/Tél : 416-977-7620
FAX/Télécopieur : 416-977-8131
E-mail/Courriel : cns-snc@on.aibn.com

BOOK REVIEW

DEEP RIVER: A Canadian Story

F. H. (Kim) Krenz
McGill-Queen's University Press

(Following is from one of the reviews of the manuscript.)

The chief objective of the book is to provide a first-hand account of the early days of the Canadian atomic energy project, and through it of the foundations of what became Canada's extensive and multi-faceted nuclear industry. The writing is lucid, effective, and wryly humorous, engaging the reader's attention quickly and easily. Complex scientific and technical concepts are neither avoided nor exaggerated, but dealt with in a clear and intelligible manner, with the interest of the general reader in mind. The device of casting the account as a tale of Deep River (the town developed to house the scientific and technical personnel of the Chalk River Nuclear Laboratories) provides a versatile means of linking general and personal developments.

A major strength of the manuscript is that it bridges the gap between general academic accounts of the project, and purely local histories. The story of Canada's transformation, during World War II, from a very junior player in scientific and technical developments into the home of world-class nuclear research and development facilities is historically important and complex. The broad lines have been told by Eggleston, Bothwell, and others. Singularly absent from the record however are personal accounts of the trials and triumphs of those who actually did the work.

Deep River: A Canadian Story is not only a good read in itself, it goes a long way toward filling a significant gap in our understanding of an exceptionally important period in our national story. As such, it is of potential interest to students of international relations, Canadian history and foreign affairs, science and technology policy, national defence, as well as the interested general reader.

(At the time of printing the book had not been issued. For further information contact the author at tel. 705-652-6330 or e-mail: kkrenz@ptbo.igs.net)

BOOK REVIEW

"Handbook on Radiation Probing, Gauging, Imaging and Analysis" Volume I: Basics and Techniques, Volume II: Applications and Design.

Esam Hussein,
Kluwer Academic Publishers, Dordrecht

This is a two-volume reference for those involved in the use of radiation for probing, gauging, imaging and analysis.

Prof. Hussein holds the chair of Mechanical Engineering at the University of New Brunswick. He was recently awarded a CNS/CNA Innovative Achievement Award at the 24th CNS Annual Conference held in Toronto, June 2003.

For more information see: < http://www.wkap.nl/prod/b/1-4020-1294-2 >

Publications available

"2002 Annual Report of OECD Nuclear Energy Agency (NEA) "

In its 2002 Annual Report, just published, the Nuclear Energy Agency (NEA) notes that during the year the nuclear option was brought back on the agenda and issues related to nuclear energy and sustainable development were addressed in several high-level meetings, including the OECD Forum 2002, the World Summit on Sustainable Development and the Eighth Conference of the Parties to the UN Framework Convention on Climate Change (COP8).

At the end of 2002, 362 nuclear power units were connected to the grid in OECD countries, providing approximately 24% of total electricity supply in the OECD area. Three new nuclear power units were brought into operation: one in the Czech Republic and two in Korea; two units were retired in the United Kingdom. Seven units were under construction: three in Japan, two in Korea and two in the Slovak Republic.

The safety performance of nuclear power plants in OECD countries continued to be very good. However, the analysis of a number of operating events which occurred in 2002 highlighted certain aspects requiring close attention, such as: organizational changes, hardware modifications, loss of technical expertise and loss of corporate knowledge.

In the area of radiological protection, the NEA published a report entitled *Society and Nuclear Energy: Towards a Better Understanding,* which analyses literature and research work on risk perception and communication, as well as public participation in decision making on nuclear energy projects.

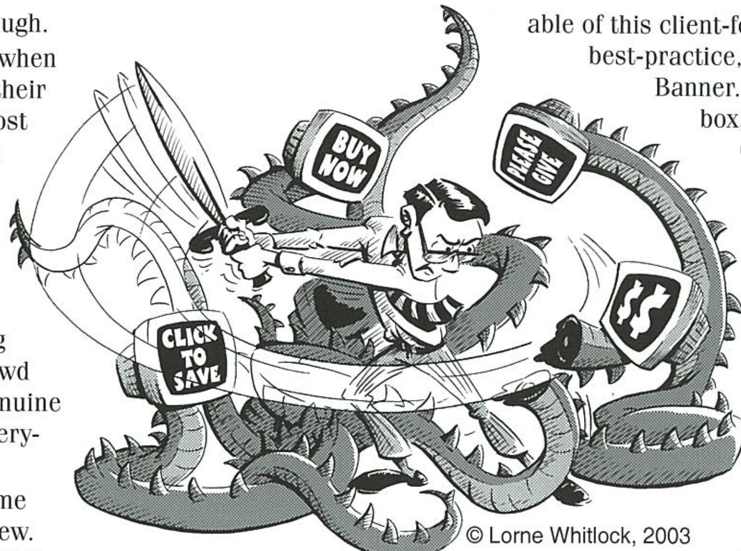
The NEA addressed the issue of public confidence in radioactive waste management through a series of workshops organized under the aegis of its Forum on Stakeholder Confidence. The third such workshop took place in Canada.

The 2002 Annual Report of the Nuclear Energy Agency is available free online at <http://www.nea.fr/html/pub/annual-report.html> or in paper format on request from: OECD/NEA Publications Office, Le Seine St. Germain, 12 boulevard des Iles, 92130 Issy-les-Moulineaux, France (neapub@nea.fr).

END POINT

The Spam Economy

by Jeremy Whitlock



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It all started innocently enough.

Nobody could quite say when the spam emails first made their appearance; in fact, it almost seemed like they'd been a part of office routine forever. With little thought, and only slight annoyance, employees had learned to pre-filter their email first thing each morning, rooting out the sales pitches and lewd propositions from the genuine pitches and propositions of everyday business.

The spam grew. The time required to deal with it grew. The techniques grew in sophistication, until even seasoned spambusters found themselves inadvertently opening invitations to try Viagra at fire-sale prices. The sad tale of Omar Haatu, and two-dozen other Nigerians with strikingly similar money troubles, was known to all. The whole world seemed to be enlarging certain body parts, while decreasing others with miracle diet pills.

And then a strange thing happened. The employees began to look forward to the morning cull. It imparted an odd sense of achievement, a reason to start the day. Management came to recognize the advantage of this, and even held back on plans to distribute anti-spam software. "Sorry, we cannot disposition that query", employees were told, and secretly they were relieved.

Here was empowerment, in a system that increasingly valued process over progress. Technical reports took ages to release, but each morning six screens of detritus could be dispatched in a half-hour's romp. Here were no pestilent Microsoft templates to tangle with, no Byzantine company procedures to humour. Here a swath through insignificance was hacked with the slightest flick of an index finger.

Drunken with victory, employees barely noticed as more and more administrivia was downloaded their way. The standard conduit of inconsequentiality, Quality Assurance, was soon swollen to overflowing. There was talk, and talk, and talk. The employees listened, and trained, and dispositioned.

One had to be seen to be listening, and training, and dispositioning. The more you listened, and trained, and dispositioned, the better. At the end of the day, when the rubber had truly hit the road, the optics-driven bottom-line deliverable of this client-focussed, value-added, proactive, best-practice, synergistic paradigm was the Banner. The Banner hangs outside the box, declaring sameness (or as the Greek say, "ISO").

The Banner is special because it is made from magical thread: only those worthy of their position can see the importance of the Banner; those who can't are truly fools. Thus, the forms flowed and the employees marched. They marched into training rooms and sat for hours in rooms with air-conditioning systems that had been broken for weeks, and learned about Quality.

They wrote down everything they could possibly say about what it was they were doing, or planned to do, until it seemed they were seldom getting around to actually doing it.

They began to sense this and tire of the task, even with the excitement of the spam hunt each morning. Management then offered a new challenge, guaranteed to occupy the keenest of minds: employees were to become their own administrative assistants. They learned, through extensive training in stifling hot rooms, how to electronically enter their timesheets, expense claims, and purchase orders into the company computer system, using one of the most obstructive user interfaces ever devised. They were well and truly busy.

And then one day, a young boy arrived for "Bring Your Child to Work Day". He was proudly shown the arrays of paper, the training certificates, the mission statements, vision statements, quality pyramids, and planning matrices. And he was shown the Banner.

The boy looked around and exclaimed, "But you have no product!"

There was stunned silence, for all realized that surely this young child must be telling the truth. They looked at each other and felt shame. Then they sent the boy home and cancelled "Bring Your Child to Work Day", and from that moment on never allowed another visitor to their site.

They went back to their computers. Mrs. Mariam Sese-Seko Mobutu was looking for assistance. A new guaranteed dating service was starting up. Black-market Viagra prices were at an all-time low.

CALENDAR

2003

Sept. 15 - 19
International Conference on Advanced Nuclear Power Plants and Global Environment
Kyoto, Japan
Contact: Atomic Energy Society of Japan
American Nuclear Society
website: genes4-anp@nuclear.jp

Sept. 22 - 24
International Conference on Supercomputing in Nuclear Applications
Paris, France
e-mail: SNA2003@cea.fr
website: www.SNA-23.cea.fr

Sept. 22 - 24
8th International CANDU Fuel Conference
Delawana Inn, Muskoka Ontario
Contact: Brock Sanderson
AECL - CRL
Tel: 613-584-8811 x3368
e-mail: sandersonb@aecl.ca

Oct. 5 - 8
Advances in Nuclear Fuel Management III
Hilton Head Island, South Carolina, USA
Contact: Bojan Petrovic
email: petrov@Westinghouse.com

Oct. 5 - 9
NURETH-10
10th International Topical Meeting on Nuclear Reactor Thermal Hydraulics
Seoul, Korea
Contact: Soon-Heung Chang
e-mail: nureth10@mail.kaist.ac.kr

Oct. 13 - 14
PLIM & PLIX Conference
New Orleans, LA, USA
Contact: Julie Rossiter
Wilmington Publishing Ltd.
e-mail: jrossiter@wilmington.co.uk
website: www.plimplex.com

Nov. 16 - 20
ANS/ENS International Winter Meeting
New Orleans, LA, USA
Contact: American Nuclear Society
e-mail: meetings@ans.org
website: www.ans.org

Nov. 16 - 18
6th International CANDU Maintenance Conference
Toronto, Ontario
Contact: CNS Office
Tel: 416-977-7620
e-mail: cns-snc@on.aibn.com

2004

Mar. 3, 4
CNA Nuclear Industry Seminar
Ottawa, Ontario
website: www.cna.ca

Mar. 28 - 31
10th International Topical Meeting on Robotics and Remote Systems
Gainesville, Florida
website: www.ans.org/meetings/robotics

Mar. 21 - 25
PBNC 14
14th Pacific Basin Nuclear Conference
Honolulu, Hawaii
website: www.ans.org/meetings/pbnc

Apr. 25 - 29
PHYSOR 2004
Chicago, Illinois
website: www.td.anl.gov/PHYSOR2004

May 2 - 6
International Topical Meeting on Advanced Nuclear Installation Safety
San Francisco, California
website: www.ans.org/meetings

May 9 - 14
10th International Conference on Radiation Shielding
Maderia, Portugal
website: www.itn.mces.pt/ICRS

May 9 - 13
IYNC3
3rd International Youth Nuclear Congress
Toronto, Ontario
Contact: Adam McLean
e-mail: adam.mclean@utoronto.ca

June 6 - 9
25th CNS Annual Conference & 29th CNS/CNA Student Conference
Toronto, Ontario
Contact: Denise Reuben
Canadian Nuclear Society
Tel: 416-977-7620
e-mail: cns-snc@on.aibn.com

June 13 - 17
ANS Annual Meeting
Pittsburgh, Pennsylvania
Contact: American Nuclear Society
website: www.ans.org

June 13 - 17
International Congress on Advances in Nuclear Power Plants
Pittsburgh, Pennsylvania
website: www.ans.org/goto/icapp04

Aug. 22 - 26
SPECTRUM 2004
Atlanta, George
website: www.ans.org/spectrum

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