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EDITORIAL

Is it time for optimism?

The theme for the upcoming 25th CNS Annual Conference *"Nuclear Energy - Meeting the Challenges"* has the implication of optimism - that we WILL meet the many challenges needed to be overcome if nuclear power is to play a significant role in our energy future. On a personal level two events over the past couple of months have provided support for that sense of optimism.

The 2004 International Youth Nuclear Congress, held in Toronto in May was one of those. To be at a nuclear meeting where most of those attending were in their 20s or 30s was reminiscent of 40 years ago when we were in that age range and nuclear gatherings had the same enthusiasm, vitality and optimism that characterised the 3rd IYNC.

Actually IYNC had its genesis in the political action of young European nuclear professional at one of the COP meetings associated with the Kyoto accord where they put on a show that outshone anything by the anti-nuclear groups. As the movement grew and spread the enthusiasm has continued.

Those young professionals from around the world are not naive. They recognize the challenges but believe in the science and technology they have embraced and are prepared to carry their beliefs to the public and political leaders. At IYNC 2004 they deliberately tackled subjects the older generation avoids, such as politics and social status, and ones that the main stream is just beginning to acknowledge, such as knowledge transfer. On that last critical issue they have experienced the chaos that results when experienced colleagues retire and take their accumulated experience and knowledge with them.

If they are supported, if they are encouraged, this new generation may yet save nuclear power and the other applications of our science and technology.

The other event providing optimism was the interview with John Murphy about human resources at Ontario Power Generation. It became evident that over the past couple of years, and especially the last few months with a new chairman, that OPG is beginning a new chapter in its relations with its most precious asset, its staff. Getting trades people to buy into a "skills broadening" program may appear trivial but is a huge step forward and a 20-fold reduction in "grievances" is a concrete example of improved relations.

There are still some discouraging situations, such as the ongoing debacle of the MAPLE project, and the still undecided future of Pickering 1, 2 and 3. Even what was intended as a sales pitch, the announcement that ACR would be commercially available in 2012, has a down size. There will be need for new electricity generation long before then. If nuclear is not economically available another choice will be made.

Nevertheless, we still enjoy that feeling of optimism.

Fred Boyd

IN THIS ISSUE

Most of the technical papers in this issue are drawn from the 14th Pacific Basin Nuclear Conference held in March 2004 and all but one are Canadian. With 23 good papers from Canada choosing just three was a challenge. Please look at the list of Canadian papers for ones that would interest you more and contact the authors or get the CD proceedings from the American Nuclear Society who organized the meeting.

We begin with a report on the **14th PBNC,** followed by a list of the **Canadian papers** presented and a short note on a workshop on **Advanced Reactor Concepts** conducted by Romney Duffey during the conference.

The first paper selected is, to us, an intriguing one about the **Chornobyl New Safe Confinement** that describes the structure proposed for a long-term encasement of the ill-fated Chernobyl 2 (to use the Russian spelling rather than the Ukrainian). Then there are the three chosen Canadian papers. **Low Doses of Radiation Reduce Risk**, by Ron Mitchell of AECL, describes results of experiments that showed low doses of low LET radiation reduced radiation-induced cancer risk in mice. **Sustaining Improved Performance at Bruce Power** reviews the comprehensive improvement program at Bruce with emphasis on the continuous assessment of the plants. In **Update on AECL's Spent Fuel Management Activities** Michael Stephens and colleagues provide a review of the many programs continuing at AECL on the spent fuel issue.

There is a report on a very enjoyable conversation with John Murphy in **Human Resources at OPG** in which he offers an insight into some of the new HR programs at OPG. That is followed by **a comment by Bertrand Barré** and a paper by Dan Meneley on **Safer Nuclear Energy for the Future** that began as an overseas lecture

Then there is our report on our most enjoyable activity of the period the **2004 International Youth Nuclear Congress** held in Toronto early May.

There is our eclectic selection of **General News**, items you may not have seen elsewhere, and, what sadly has become common over the past two or so years, three **Obituaries.**

The section on **CNS News** provides some insight into the many activities of the Society and we close with the incomparable thoughts of Jeremy Whitlock in **Endpoint** and an updated **Calendar** of events you might consider attending.

As always we welcome your reaction and invite your input.

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Cover Photo

The cover photograph shows the Roy Errington Building, the headquarters of MDS Nordion, in the Ottawa suburb of Kanata, with a glimpse of the isotope production facilities attached.

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14th Pacific Basin Nuclear Conference

Strong Canadian presence at PBNC

The Canadian delegation to the 14th Pacific Basin Nuclear Conference (PBNC14) held in Hawaii, March 21 - 25, 2004, was among the largest of the many countries represented. Canadians presented two plenary papers, 23 technical ones, chaired five sessions and conducted an interesting workshop on advanced reactors..

In particular, three technical sessions, all on "Adaptive Response Following Low dose Radiation Exposure", were organized by **Jerry Cuttler,** former CNS president. Those sessions included papers from Australia, China, Japan, Mexico, Taiwan, USA as well as Canada. *(One of the Canadian papers on this topic, by* ***Ron Mitchell*** *of AECL Chalk River, is reprinted in this issue of the CNS Bulletin along with a few other selected ones.)*

The Pacific Basin Nuclear Conferences are held every two years in one of the countries with membership in the Pacific Nuclear Council (PNC), the authorizing body for the meetings. This one was organized by the American Nuclear Society. The PNC is composed of nuclear societies and associations from countries around the Pacific rim.

Overall attendance was modest at about 360, little more than half that at the last Canadian-hosted PBNC in Banff in 1998, but closer to recent ones in China and Korea. Surprisingly, attendance from the USA was small, reportedly because many US firms are reluctant to send people to meetings in Hawaii.

In addition to the basic program an interesting and well-attended workshop on Advanced Rectors was held by **Romney Duffey,** AECL's Principal Scientist, as part of a PNC initiative. *(See separate article.)*

The opening plenary session began as usual with greetings and comments from local dignitaries, the ANS, conference organizers, and **Paul Fehrenbach,** AECL vice-president, who is the incoming president of the PNC. *(See separate article.)* Paul emphasized the role of the PBNC meetings in the global sharing of information in the nuclear field.

Paul Fehrenbach, newly elected presidnet of the Pacifgic Nuclear Counci (centre) recieves a cheque for $10,000 on behalf of the PNC from PBNC 14 co-chairs Gail Marcus (L) and James Reinsch.

Three substantive papers followed. **Glen McCullough,** chairman of TVA and honorary chair of PBNC 14 gave his perceptions on "The Foundations for Nuclear Revival in the USA". Continued good operation is essential , he said, noting that the capacity factor of US nuclear plants had reached over 89 percent from a low of about 60 percent in the 1980s. This has partially come about by the significant reduction in the length of refuelling outages, now as short as 15 days.

Generating costs from US nuclear plants now averaged about 1.7 cents/kwhr. Significant events had dropped from 0.9 per unit per year in 1989 to 0.03 in 2002. He acknowledged that performance was poorer in 2003 but said this was largely due to the August blackout in northeastern USA and Canada. Urging cooperation and collective good operation he closed with a quote from the American revolution, "We must hang together or we will hang separately."

Louis Echaverri, director general of the Nuclear Energy Agency of the OECD, provided a broad perspective of nuclear power in OECD countries which, he noted, included six Pacific countries represented at the conference: Australia, Canada, Japan, Korea, Russia, USA. The average capacity factor of nuclear plants in all OECD counties was 84 percent in 2002, up 10 percentage points from 1992. About 24 percent of the electricity in OECD countries is generated by nuclear power.

He noted that deregulation had made nuclear, with its high capital cost, not favoured by the investment community. Proliferation and security concerns further worked against an early resurgence of nuclear plants in most OECD counties.

Greta Dicus, former USNRC commissioner and now the most recent US appointment to the International Commission on Radiological Protection (ICRP), gave a presentation that many found disturbing. She read from a draft of ICRP's new basic recommendations but said it was confidential until May 2004.

ICRP is not changing its basic recommendations in ICRP 60, the international "gospel" since 1990, she emphasized.

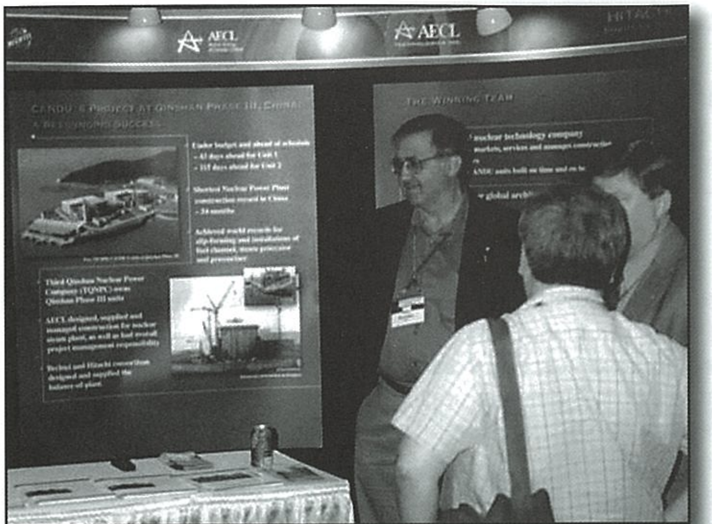
There is a probability of an [adverse] effect even at very low levels of radiation dose, she contended. Therefore the ALARA (As Low AS Reasonably Achievable) concept will be re-emphasized. Protection of non-human biota will be proposed as ICRP no longer accepts the premise that if humans are protected so will be other species. Acknowledging that "collective dose" had been misused the new report will try to clarify its proper application.

She closed with a story of taking her mother to a restaurant after having a nuclear medicine diagnosis in which she was injected with the [very short half-life] isotope Molybdenum 99 and being concerned about the radiation dose her mother was giving to those sitting nearby !! Incredibly, she repeated the story when she chaired a session later in the conference.

In the second plenary session, **Helen Leiser,** policy director, Generation IV International Forum (GIF), described the structure and organization of GIF, the multi-country organization coordinating work in several countries (including Canada) on very advanced concepts for nuclear power reactors. GIF is organized with a "policy group", an "experts group" chaired by the USA with members from all countries, and two working groups, one on economic modeling, and the other on "proliferation resistance and physical protection". Both working groups are trying to develop agreed standard methods for the evaluation of different designs. There is a small policy and organization secretariat based in Washington, D.C. and a technical secretariat is planned, to be based in Paris. She closed by noting that the program presents unique challenges, technical, regulatory and political. *(More information on the Generation IV International Forum can be found at the website <gen-iv.ne.doe.gov>)*

Another international view was given by **Yury Sokolov,** deputy director general, International Atomic Energy Agency. He noted international trends of improved capacity factors, life extensions and cost reductions. Against this are on-going problems of ageing, both structures and people, accumulation of waste and deregulation. There is a need for an holistic approach to encompass economics, safety, proliferation, waste and all other aspects of nuclear power.

Then he spoke briefly about research reactors, most of which were built several decades ago and, he said, are largely underused.



The booth of Atomic Energy of Canada Limited at PBNC 14.

Mikhail Solonin, first deputy minister, Minatom, Russia, who spoke through a translator, noted that Russia was involved in the entire nuclear fuel cycle, mining, enrichment, fuel manufacturing, spent fuel processing and storage. All Russian enrichment is now being done by centrifuge. He mentioned Russia's participation in GIF and spoke briefly about their design for a very high temperature gas-cooled reactor which could have an efficiency of 50 percent.

Chang-Sun Kang, from Seoul National University in Korea, spoke of their SMART (small and medium sized advanced rector technology) program. The basic design report was issued in 2002, the complete design is scheduled for 2005 and a 1/5 scale pilot plant built by 2009.

Yuanhui Xu, from Tsinghua University, China, outlined their work on high temperature reactors which began in 1981. They have a 10 MWe demonstration plant in operation and plan to have a 150 MWe pilot plant by 2006. This is a gas-cooled design, using a concrete pressure vessel and spherical fuel.

There were two further plenary sessions, one on "near term challenges" the other on "new developments in nuclear technology applications". The latter included three "country reports" from Argentina, Taiwan and Thailand.

Among the other presentations, **Matt Forsbacka,** of NASA, spoke on that organization's "PROMETHEUS" project for the application of fission for future space travel. They are looking at advanced concepts involving very high temperature gas or lithium cooled designs and an ion engine. He showed a conceptual design of a space station with the reactor mounted far away from the inhabited part.

Grant Malkoske, of MDS Nordion, gave a historical review of the use of radioisotopes in the medical field, including a video of a "virtual hospital".

Finally, **Ron Cameron,** executive director of ANSTO (Australian Nuclear Science and Technology Organization) gave a fascinating account of how they overcame a major potential impediment in the construction of their new research reactor when a seismic fault was discovered during excavation for the reactor building. Two fault strands were uncovered. Although the plant had been designed for a 0.37 g acceleration, based on a 10,000 year return period, the regulatory agency halted construction until the significance of the faults could be determined. After exhaustive review it was finally determined that the faults related back to the time of the separation of New Zealand from Australia some 83 million years ago. On that determination construction was allowed to resume, with just four months lost in the schedule.

The closing session on the Thursday afternoon began with conference co-chair **Gail Marcus** commenting on the diverse nature of the meeting and thanking the 360 delegates from 12 countries who had attended. She noted that most of the 200 technical papers were included on the conference CD but commented that none of the plenary presentations were included. Then she and co-chair **James Reinsch** handed a cheque for $10,000 (US) to Paul Fehrenbach, as president of the Pacific Nuclear Council, in return for the authority to hold the conference. This is a practice Canada began at the 1998 PBNC in Banff.

Three persons gave their impressions of different aspects of the conference. **Rolland Langley** looked at international cooperation with a reference back to December 1953 when US president Eisenhower gave his "Atoms for Peace" speech that eventually led to the creation of the International Atomic Energy Agency. Mentioning Three Mile Island and Chernobyl he commented that an accident anywhere is an accident everywhere. But those events did lead to the development of INPO and WANO, which had helped improve the operation and safety of nuclear plants around the world. He singled out the paper by **Ben Rouben** which described a "virtual" team with members from Argentina and Canada who worked together but never met.

AECL's **Shami Dua** reviewed the papers related to standards and urged participation in the work of a PNC Task Group, which he chairs, to collect information on all the standards used by the member countries of PNC.

Yasumasa Tanaka, of Japan, spoke about the three sessions on Public Information and Outreach mentioning in particular papers on communicating with women and the use of retirees in speaking to the public. He complimented the Canadian Nuclear Association for its website.

Finally, **Clarence Hardy,** of Australia, extended an official invitation to attend PBNC 15 to be held in Sydney, Australia, October 15 -2 0, 2006. That was followed by an impressive video displaying the many attractions of that city.

There was also a modest exhibit area associated with the conference at which AECL had a booth.

Canadian papers at PBNC 14

Following are the papers presented by Canadian authors at the Pacific Basin Nuclear Conference held in Hawaii, USA, March 21-25, 2004. The technical papers are included on a CD of the conference, available from the American Nuclear Society. Individual papers are likely available from the authors. No copies of the plenary presentations are available.

Plenary:

New Nuclear in North America - A Canadian Perspective on the Path Forward
Robert Van Adel (AECL)

New Applications of Radiation Technology to Advance Global Health
Grant Malkoske (MDS Nordion)

Technical:

Development of an In Vivo Assay for Detection of Non-Targeted Radiation Effects
Colin Seymour, Carmel Mothersill (McMaster University)

The Adaptive Response and Protection Against Heritable Mutations and Fetal Malformation
D. R. Boreham (McMaster University) et al

Update on AECL's Spent Fuel Management Activities
M. E. Stephens et al (AECL)

CANDU and Generation IV System
R. B. Duffey et al (AECL)

ACR Modularization
J. Blevins et al (AECL)

Fuel Cycle Flexibility in the ACR
G. R. Dyck, P. G. Boczar (AECL)

ACR Application to Oil Sands
J. M. Hopwood et al (AECL), B, Dunbar (CERI)

The Role of the Internet in Public Policy Making
Claudia Lemieuz (CNA)

Low Doses of Radiation Reduce Risk In Vivo
R. E. J. Mitchell (AECL)

Radiation Induced Bystander Effects: Evidence for an Adaptive Response to Low Dose Exposures?
Carmel Mothersill (McMaster University)

Radiological Emergency Response: The National Biological Dosimetry Response Plan
J. A. Dolling (Credit Valley Hospital, D. R. Boreham (McMaster University)

CSA N286 - Management System Requirements for Nuclear Power Plants - A New Standard for Canada's Nuclear Power Plant Industry
R. Abel (R&M Abel consultants Inc.)

Evaluation of the Reliability of Design (Research & Development) Practices in Support of Regulatory Requirements
Eugene Sokolov (AECL)

International Collaboration to Study the Feasibility of Implementing the Use of Slightly Enriched Uranium fuel in the Embalse CANDU Reactor
B. Rouen et al (AECL), J, Fink et al (Nucleoelectrica Argentina S.A.)

Construction of CANDU in China: An International Success
K. Petrunik (AECL) et al

International Co-operation in Licensability Review of the Advanced CANDU Reactor
G. Rzentkowski (CNSC)

What Becomes of Nuclear Risk Assessment in Light of Radiation Hormesis ?
Jerry Cuttler (Cuttler & Assoc.)

New Nuclear - Delivering on the Promise
J. Polcyn (AECL Technologies , K. Hedges (AECL)

NPP Performance Improvement Through OPEX
Brian MacTavish, Malcolm Lightfoot (COG)

A Review and Update of Bruce Power's Program to Sustain Improvements to its Nuclear Plant Performance
R. E. Tout (Bruce Power), Raidis Zemdegs, Jordan Chou (Canadian Nuclear Utility Services)

Utilizing Plant Life Management Methodologies to Improve Capacity Factors
S. Azeez et al (AECL)

Start-Up of a Nuclear Engineering Undergraduate Honours Degree Program in Canada
George Bereznai (UOIT)

CNSC Development Program for the Recruitment of Young Engineers and Scientists
Amy Moore (CNSC)

How Safe is Safe Enough ?
Fred Boyd (Wild & Boyd Ltd.)

Independent Assessment in a Learning Organization
John Krane (Bruce Power)

Advanced reactor concepts

A Canadian organized workshop held during the 14th Pacific Basin Nuclear Conference in Hawaii, March 2004, explored various designs being considered by Pacific Rim countries for future nuclear power stations. The workshop, which was part of an ongoing program of the Pacific Nuclear Council, was organized and chaired by Dr. Romney Duffey, principal scientist at Atomic Energy of Canada Limited who also chairs the PNC Task Group on Advanced and Next Generation Systems. The following article is based on Dr. Duffey's draft notes on the workshop.

Representatives of eight countries from around the Pacific Rim, most of whom have societies that are members of the Pacific Nuclear Council, joined in a half-day workshop in Hawaii during the 14th Pacific Basin Nuclear Conference to compare notes on the status of advanced and next generation nuclear power designs. The countries represented were: Argentina, Australia, Canada Chile, Japan, Korea, Mexico and Taiwan. There were also reports from Russia and Thailand.

The objectives of the workshop were:

- To provide for a description and dialog on status of Advanced and Next Generation Systems, waste and fuel cycles among PNC members
- To establish an up-to-date overview of alternative approaches, timeframes, development and implementation for new builds
- To establish open communication on proposed and actual directions, and on open issues, between all Pacific basin countries
- To provide and explore connections between differing initiatives in different countries and national groupings.

From the presentations and estimates made at the Workshop, Pacific Rim countries will likely be pursuing the new technology options shown in Table 1. The options and timing largely reflect the Generation IV Roadmap descriptions.

Despite the uncertainties in any such estimate, it is clear that the Pacific Rim will be the host to approximately *20 new builds over the next 5 years* (2005-2010), and as many as *40 for the next interval 2010-2025.* This number is a major growth, and shows the importance of the region in the nuclear future.

The reactor types for this build effort are Generation III+ evolutionary designs. Any advanced concept (e.g. Generation IV) is seen as following that timeframe, consistent with present long-term technology development timeframes and programs.

There was a clear division between established and new or emerging markets.

a) In new nuclear countries/markets, reactor choice was not a technology issue. In fact, it was stated that if anything there are too many competitive choices for the near term options. The reactor types must meet stringent market conditions, which are economic driven and dominated for new builds. There was a trend to smaller unit size to fit developing grid and distribution structures, as well as energy growth demand.
b) In established countries/markets, for reactor choice there was a trend to larger unit size, again to reduce the costs of generation. The reactor types were now largely of national origin as a mark of independence, and hence with restricted competition. The preferred unit size varied with industrial, economic and national factors.

The major competition is the price of local gas generation, but a main driver is also the increasing cost of gas supply, up by many times in some countries compared to just a few years ago.

The need for investment in new technology is predicated by the fact that the longer-term effort (e.g. on Generation IV) will be government funded, as it is high risk and long term pre-commercial in nature. In addition, there is a chance to share R&D, by joint programs, the GIF and other initiatives. There is also a need to have the new market countries involved in new technology development, and at the very least to be informed.

It was clear that thermal reactor concepts will most likely be deployed sooner than the fast reactor options although China reported on its active development of a fast reactor.

Research and development on hydrogen production, reactor choice and alternate fuel cycles are being pursued in countries with an already established nuclear component.

The group concluded that:

- Advanced and Next Generation Systems (ANGS) are expected to be relatively cheaper, safer, and environmentally friendly, and have a performance and operation that is superior. The systems are expected to be so-called Generation III+ (evolutions of and advances from today's designs) for the short-term deployment from 2005-2020. More advanced and somewhat more

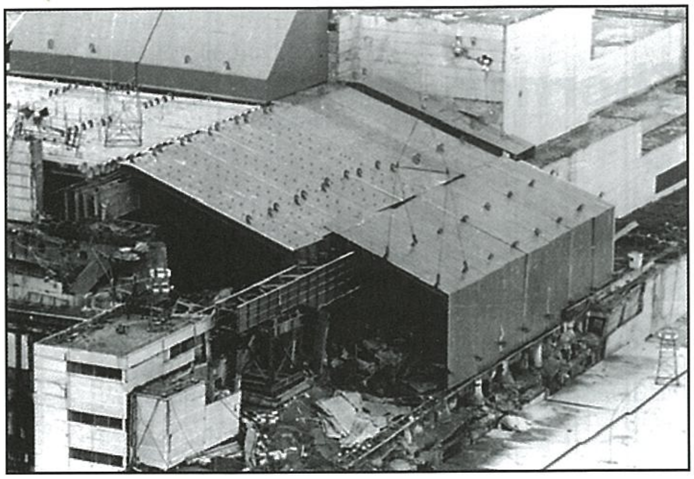


Figure 1: Object Shelter during construction

pipes are visibly resting on the southern B-2 beam. Resting on the B-1 beam at the top, and the mammoth beam on the bottom, are the southern roof panels. A "hockey stick" panel is being placed with its upper edge resting on the mammoth beam, and its lower edge resting on the octopus beam.

I.B. Chornobyl Exclusion Zone

The population of heavily contaminated land was evacuated 1986, and from certain other areas in 1987–2000. The evacuated areas are referred to as the Chornobyl Exclusion Zone (CEZ). The boundaries of the CEZ were established by Decree No. 106 dated 23 July 1991. The CEZ is a Ukrainian territory extending from west to east about 110 km and from north to south about 35-45 km. The total land area of the Chornobyl Exclusion Zone is about 2,500 square kilometers.

II. STRUCTURAL DESIGN

II.A. Shape and Dimensions

The New Safe Confinement design is an arch shape structure with an internal height of 98.3 m, a 12 m distance between top and bottom chord centerlines, an internal span of 245 m and an external span of 270 m. The arch shape was a programmatic decision made prior to the beginning of conceptual design. The dimensions of the arch were determined during conceptual design as the optimum dimensions needed to accomplish deconstruction activities under the arch (see Section IV).

The structure is 150 m long with plane vertical walls on either end of its length. The 150 m length of the arch is comprised of 12 bays and 13 arch frames that are placed at 12.5 m on center. The end walls are built around, but not supported by the existing structures of

ChNPP. The end walls, where possible, have been laterally supported at the base to reduce the need for cantilevered sections.

The arch is constructed of tubular section members made of steel. The arch has an external cladding of threelayer sandwiched panels. Similar panels are used for external cladding of the end walls. An internal polycarbonate cladding over the internal chord of the arch prevents accumulation of radioactively contaminated dust on the framing members. The structure will be assembled at a staging area

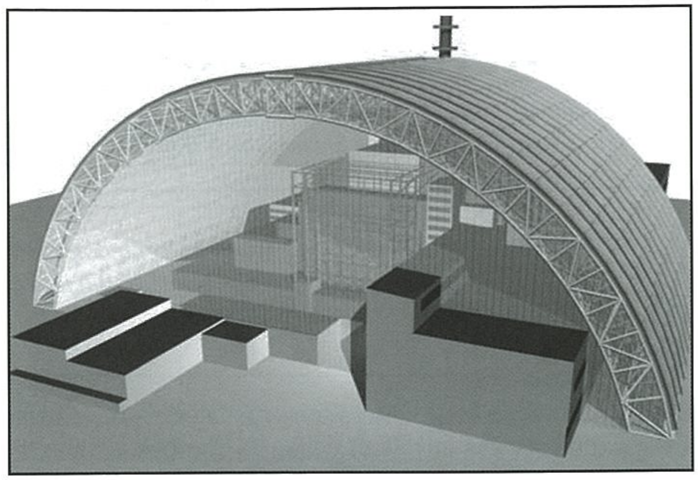


Figure 2: Rendering of NSC

in segments and jacked, or pulled, into its final location.

An architectural rendering of the arch is provided in Figure 2, viewed from west looking east. The building extending out of the right (southern) end of the west wall is the ChNPP Unit 4 turbine hall. The structures extending out of the left (northern) end of the west wall are the fragmentation, decontamination, and auxiliary buildings described in Section IV.

II.B. Structural Design Process

GTSTRUDL™ (Georgia Tech Research Corporation), Release 25, was used to determine the arch members based on the loading defined in SNIP 2.01.07- 85. Eight variants were analyzed. The parameters which differentiated the variants were arch shape (circular or parabolic), arch thickness (constant or tapered), and arch attachment to the foundation (hinged connection on the outer arch chord attachment, or hinged connection and simple support on the outer and inner arch chord attachment). Selection criteria were minimization of mass of steel, minimization of horizontal reaction forces on foundation, and optimizing constructability.

The weight of the steel framing was determined for each of the eight variants. The calculation selects the lightest member size available in a table based on the calculated forces. This can lead to extreme variation in chord diameters that does not yield a constructible solution. However, for the purposes of establishing a baseline for selecting a configuration, this is an acceptable procedure.

The maximum horizontal and vertical reactions for each configuration were then evaluated. The fixed arch configurations, i.e., the arches with 2 supports at each end of the span, were eliminated due to the moment that would be imposed on the foundation. A hinged arch will allow for a more compact foundation since the reactions are limited to horizontal and vertical forces.

To evaluate competing variants on the basis of construc-

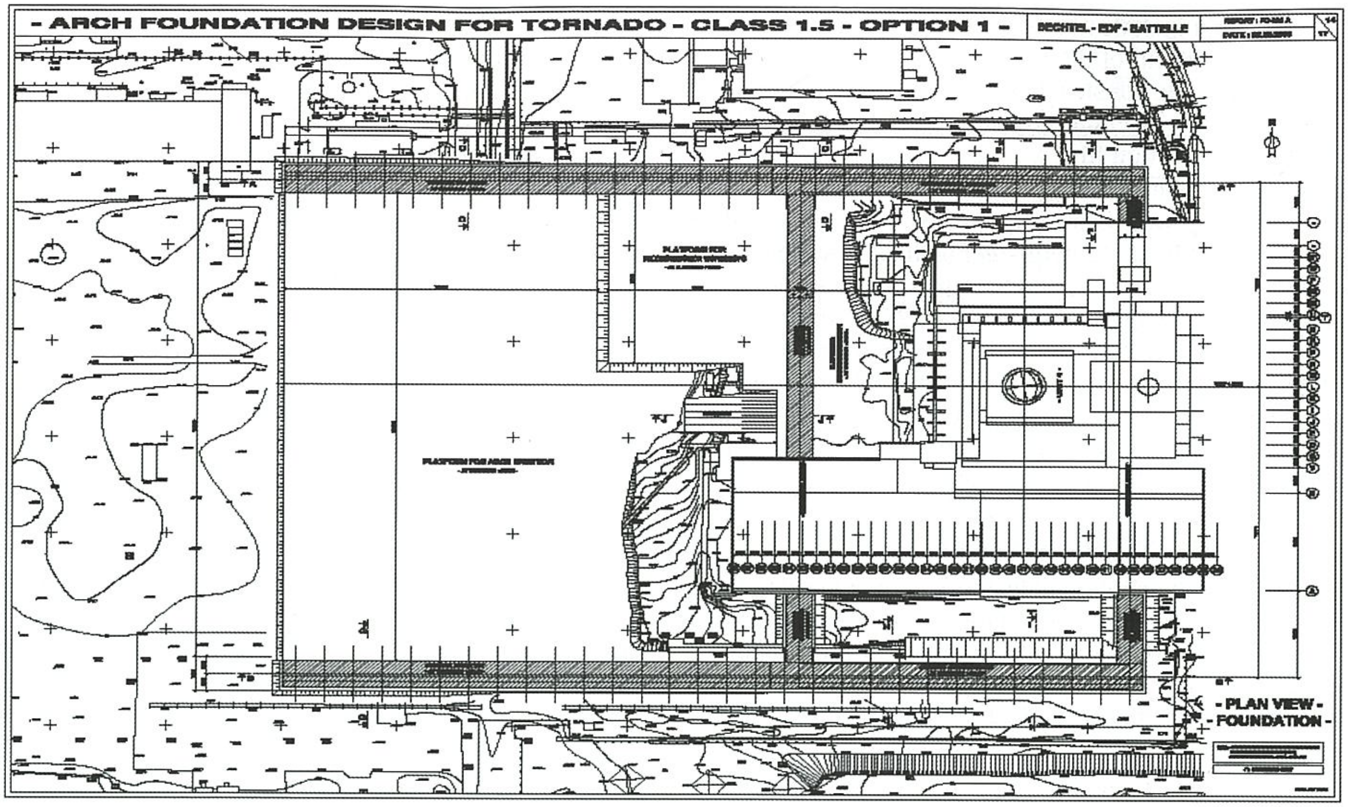


Figure 3: Site Plan and Topographic Drawing, illustrating foundation and assembly area location s.

tability, arch member sizes were constrained to provide similar diameters along the chords. Also, the bracing and the post members were grouped to minimize sizes. Parabolic arches and tapered arches were eliminated because of the large number of various member lengths of braces and struts. The height of the parabolic arch is 6 meters greater than the circular arch, which would increase wind loading and siding material significantly greater than circular arches. A circular arch also allows all roof panels to be identical, thus improving constructability.

A single variant was selected for further design development as it minimized materials consumption, minimized horizontal reaction forces on the foundation, and simplified fabrication and construction. The variant selected was confirmed by independent calculations.

Seismic loads used were equivalent static loads based on a simplified approach from the 1997 Uniform Building Code (UBC). UBC indicates that the Ukraine is located in Seismic Zone 0. The seismic zone 1 and soil type parameters were conservatively selected to establish the horizontal acceleration design load. Using an importance factor of 1.5, the maximum horizontal acceleration was determined to be 0.08g. Detailed design will include dynamic seismic analysis.

The wind loads were determined using SNIP 2.01.07-85. Wind loads govern arch structural design. Snow loads and thermal loads are based on site meteorological data and Ukrainian design normatives.

After the conceptual design had started, the standard for tornado loads was revised by the State Committee of Construction and Architecture of Ukraine (Derzhbud), increasing the load from a Class F-1.5 to a Class F-3.0 tornado. The conceptual design was completed based upon original design loads. Kyiv National University of Construction and Architecture was contracted to independently perform a beyond-design-basis-analysis of the impact of a Class F-3.0 tornado on the structure and to perform a consequence estimate (radiation dose to workers and the public) if structural failure appears probable when Class F-3.0 tornado loads are imposed on the structure designed for Class F-1.5.

II.C. Arch Construction and Material

Large parts of arch sections will be shop fabricated and transported to the assembly area illustrated in Figure 3. Two methods of arch section assembly were investigated during conceptual design: (1) the use of a mobile "goliath" crane and (2) the use of mobile strand jacks. The use of strand jacks was found preferable to a crane because of the reduction in worker dose and decontamination risk reduction.

Arch sections are individually erected and connected to form an arch bay. The eastern wall, which is a skyline cut-out of the Object Shelter shape is attached to the first bay. When three adjacent arch bays have been constructed and connected, the partially constructed arch is slid to the east sufficiently to allow construction of adjacent bays. Infrastructure (plumbing, lighting, electrical, ventilation systems, etc.) is installed in each bay during erection. The final bay erection includes installation of the western wall, which is also a cut-out of the Object Shelter shape. Cranes are installed into the constructed building before the entire building is slid into its final position. Sliding technologies are discussed in Section III.

The initial member type for the arch was hollow pipe sections. The arch was also analyzed assuming rolled wide flange sections of high-strength steel with yield strength of approximately 3500 kg/cm^2, and with pipe sections of both low-strength steel with yield strength of 2500 kg/cm^2 and high-strength steel. Even with using the high-strength steel, the weight of the arch is considerably greater constructed with wide flange sections than the constructed weight using low-strength pipe. Lowstrength steel pipe was used to provide a conservative capital cost estimate.

III. FOUNDATION DESIGN

The objective the foundation design was to determine the adequacy of different arch foundation systems to control and safely transfer the arch induced loads to the supporting ground layers and to minimize the volume of cuts into radioactively contaminated upper layers.

III.A. Soils Description

Foundations will be constructed under each side of the arch in its final resting position and extended to its assembly area, about 180 m to the west. The site slopes from an elevation of +117.5 m at its eastern extremity to an elevation of +114 at its western extremity. A foundation plan view is provided in Figure 3.

Beneath the surface is a "technogenic layer" between 1.0 and 2.5 m thick. This layer was created after the accident and consists of various materials, such as radioactive accident debris, crushed stone, sand, loamy sands, concrete (apparently unreinforced), and construction wastes. It was not possible to derive geotechnical parameters for foundation design, so the design assumes no load bearing characteristics for the technogenic layer. The water table level fluctuates from elevation +109.9 m in December to +110.7 m in May.

III.B. Foundation System

Detailed calculations were performed for three different types of arch foundation systems to support the arch at its final location:

A foundation system consisting of four lines of six one-meter diameter piles nineteen and a half meters long, and a four-meter high pile cap with pile cap top at elevation at +114 m, Option 1.

A foundation system consisting of three lines of two 4.50 m x 1.00 m foundation panels nineteen meters long, and a four-meter high pile cap with pile cap top at elevation at +118 m, Option 2.

A foundation system consisting of three lines of two 4.50 m x 1.00 m foundation panels twenty-one meter long, and a four-meter high pile cap with pile cap top at elevation at +120 m, Option 3.

The third option was found to simultaneously minimize: cost, volume of cuts in active layers, dose uptake, and risk to the environment. The arch foundation system for the third option provides foundation panels every twelve and a half meters (distance between two consecutive arch supports) along its length.

The foundation designed for the arch assembly and sliding areas is slightly different from the foundation system designed for the final resting place of the arch.

Three lines of two 4.50 m x 1.00 m foundation panels, eighteen and a half meter long, and, a three-meter thick pile cap with pile cap top at elevation at +120.00 m BAS (Baltic Altitude System) along the Assembly area.

The foundation panels are embedded into the layers of floodplain, gully, beach, riverbed and washout facies classified $a_3\ ^2pr$, $a_3\ ^2st$, $a_3\ ^2pl$, $a_3\ ^2pt$, and $a_3\ ^22rf$.

The foundation panel toe rests at elevation +95.00 m. The pile toe is either into the middle quaternary alluvial deposits classified a_2 or into the washout facies classified $a_3\ ^2rf$.

III.C. Foundation Construction and Material

A unique aspect of foundation construction at the Chornobyl site is the radioactive contamination of excavated material. Because the upper layers of the soil are contaminated, special measures are necessary to protect workers and to protect against further contamination of ground water. Both concerns favor construction methodologies that minimize excavation. For piles construction, conceptual design recommends excavation of the first 0.3 m by rope operated grabs followed by hydraulically operated clamshells under bentonite slurry protection. Thixotropic properties of the support fluid can be designed to form a filter cake preventing radioactive substance transfer by clogging the surrounding soil column.

The Client is actively considering early removal of the most contaminated upper soil layers to reduce construction contractor risk.

The pile cap and foundation concrete volumes are respectively 900.0 m^3 and 567.0 m^3 for a 12.5 m arch foundation width. A reasonable estimation of the pile cap reinforcement ratio is 150 kg/m^3. The foundation longitudinal and transverse reinforcement ratios are approximately 65.0 kg/m^3 and 30.0 kg/m^3. The pile cap and foundation reinforcement quantities are respectively 135.0 tons and 54.0 tons for a 12.5 m arch foundation width. For each meter length of the arch foundation, the concrete and reinforcement quantities are roughly 117 m^3/m and 15 t/m.

III.D. Sliding

The arch sliding system is derived from incremental bridge launching and bridge cantilever methods. Several technologies developed for these civil applications were found suitable for the arch sliding system. The movement of the structure can be obtained either by: (1) pulling with post-tensioned bundled multi-strand tendons attached at one end by dead-end anchorages to the arch base and at the other end by active anchorages to a pulling jack supporting structure, or (2) pushing the structure by direct action on the lifting jacks on a spreader beam. The sliding can be obtained either by: (1) using off-the-shelf elastomeric bearings reinforced with integrally bonded steel plates, or (2) using off-the-shelf sliding bearings made of chloroprene rubber encapsulated between a cylindrical steel container and a cylindrical steel cover, or (3) using specifically designed rollers.

Because a sliding technique providing control on the friction coefficient both by design and by constant tests during manufacture and installation is preferred, four 0.6 m by 0.6 m elastomeric bearings under each side of the arch are recommended. The bearings will rest on a stainless steel plate atop the foundation cap. The pulling technique was found preferable to a jacking/pushing technique since the pushing jacks have to be removed and repositioned between arch sliding sequences. The pulling jacks will be installed at the east end of the sliding way on a pulling jack supporting structure. A 2.5 m wide by 2 m high lateral guiding corbel was found sufficient to resist horizontal forces during sliding. Pulling the constructed arch from its assembly area to its final resting place will take slightly less than 24 hours.

Element	Quantity	Mass of each (tons)	Length (m)
Southern flat roof panels	6	31	28.7
Southern flat roof panels	6	16	28.7
Southern hockey stick panels	12	38	25.5
Mammoth beam	1	127	70
Northern beam B1	1	65	55
Southern beam B1	1	65	55
Northern hockey stick panels	18	9	18
Eastern hockey stick panels	1	7.25	7
Western hockey stick panels	4	20	15.5
Light roof	6	21	36
Piping roof	27	20	36
Northern beam B2	1	57	40
Southern beam B2	1	57	40

Table 1: Unstable structures to be deconstructed.

IV. DECONSTRUCTION DESIGN

IV.A. Design Approach

Deconstruction design followed the following logical approach :

1. Define the unstable structures requiring deconstruction,
2. Determine the maximum load to lift and the maximum dimensions of deconstructed elements,
3. Determine the deconstruction scenarios of the main elements in order to bound the laydown area dimensions, the swing radius and the handling device design load,
4. Define the basic features of the deconstruction facilities and their implementation,
5. Locate the transportation corridors,
6. Estimate the waste quantities and the area required for buffer storage.

Deconstruction design results set functional parameters that were captured in design criteria for the facility. Arch dimensions described in Section II of this paper were based upon the results of this analysis. Since cranes are suspended from the arch structure, their use imposes significant loads on the arch structure and the on foundation design described in Section III above.

IV.B. Deconstruction Design Results

The unstable structures to be deconstructed are listed in Table I.

Deconstruction requires four bridge cranes suspended from the arch with an east-west travel, and each with a span of 42 m and a lifting capacity of 50 tons. The total weight of each bridge (beams + carriage + 50 tons load) is 155 tons. One crane has a telescoping arm with 75 m extension and fitted with a variety of end effectors useful for deconstruction.

Cranes are specified with carriages that can move from one crane to another. Three types of carriages have been designed:

- two "classic" lifting carriages, each with 50T capacity,
- one secure lifting carriage for shielded transportation of personnel, 40T capacity,
- one carriage with a telescoping arm (75 m extension and fitted with a variety of end effectors useful for deconstruction).

The capacity of the carriages to move from one bridge crane to another allows the rotation of the longest dismantled elements while they are hung from the cranes and thus makes possible a reduction in the length of the confinement building (about one arch bay).

The decontamination, fragmentation, and packaging facilities extending through the west wall of the arch have a footprint of 4,350 m^2. The covered buffer storage provided under the arch is 1815 m^2. Consideration was given to use of the cascade wall as storage area (3,658 m^2).

Currently available technologies were evaluated for use in deconstruction activities. Selection criteria included minimization of individual and collective doses and minimization of cost of operation. The most important factors were: the amount of secondary waste generated, feasibility of remote operation, cutting rate, fire safety, and capital and operating costs. Selected fragmentation technologies included plasma arc cutting torches for metal beams, diamond circular cutting wheel for mid-sized concrete elements, diamond wire cutting for large-size elements. The greatest amount of radioactive contamination on deconstructed material will be loose surface contamination (dust). Selected decontamination technologies include vacuums with HEPA exhaust filters for general use, grit blasting for metallic elements, and scarifying for concrete elements. Based upon the deconstruction and decontamination technologies selected, estimates were made for deconstruction schedule and NSC operations staffing.

IV.C. Deconstruction Material

The structures to be deconstructed are characterized as follows:

- Steel
  - flat (roof panels)
  - three dimensional (pipes, trusses, beams)
- Reinforced concrete
  - pre-cast
  - cast in place
- Debris
  - Fragments of steel structures and equipment,
  - Fragments of reinforced concrete structures,
  - Materials added after the explosion for mitigation of accident consequences.

The structures scheduled for deconstruction as soon as possible after NSC completion represent 1,228 t of steel with an estimated volume (without compaction) of 1,754 m^3. The structures scheduled for deconstruction after a policy on the fuel containing material (FCM) removal is determined are 2,438 t of concrete and debris with an estimated volume of 1,875 m^3 and 1,018 t of steel with an estimated volume (without compaction) of 1,454 m^3 .

It is estimated that Low and Intermediate Level Wastes-Short Lived Wastes (LILW-SL) will compose the great majority (about 70% volume and in weight) of the wastes produced during the deconstruction and treatment activities. It is expected that Low and Intermediate Level Wastes-Long Lived Wastes (LILW-LL) will be found or produced in quantities that represent the majority of the balance (about 25%) of deconstruction waste. High Level Waste (HLW), like FCM pieces, may be found during the deconstruction activities, but are expected to constitute less than 5% of deconstruction total waste volume and mass.

The structures scheduled for deconstruction as soon as possible after NSC completion will be decontaminated to the maximum extent practical. It is reasonable to expect most of these wastes to be classified as Exempted Wastes after decontamination.

V. REGULATORY REVIEW OF DESIGN

At the time of preparation of this manuscript, four documents are being evaluated by Ukrainian regulatory authorities: (1) an explanatory note that briefly describes the conceptual design technical solutions and has as attachments about 33 design documents, (2) an environmental impact assessment, (3) a prevention of potential exposure report, and (4) the design criteria. Key elements of some of these documents are described here.

The use of the name "confinement" for this building, rather than the term "containment" traditionally used for commercial nuclear power plant reactor buildings, is intentional. It is essential in a containment building to prevent the uncontrolled release of radioactive gases following a reactor accident, but the greatest hazard to be prevented by the NSC is uncontrolled release of radioactive dust particles following an Object Shelter collapse. While gases must be contained for a long period of time, it is necessary to confine particulate for a relatively short period of time until the hazard is removed by settling.

V.A. Environmental Impact Assessment

An Environmental Impact Assessment (EIA) was prepared in accordance with Ukrainian DBN A.2.2.1-95, a prescriptive normative that results in an analysis similar to the Environmental Impact Statement process required by the National Environmental Policy Act in the United States.

The EIA assessed the environmental impacts of NSC construction, operation, and accidents. Because of the history of the site and environmental legacy of the 1986 accident, the environmental impact of accidents during NSC construction and operation received the most detailed analyses.

The bounding accident analyzed was the collapse of the object shelter during NSC construction, during sliding of the NSC, and during NSC operation. An accident source term was developed that included quantity of dust released by collapse, particle size distribution, and radionuclide distribution.

The radioactive dust cloud generated by Object Shelter collapse was transported across the CEZ by conservative models based on the Gaussian dispersion models used in many safety analyses and environmental impact analyses. The basic models were modified to account the initial dimensions of the cloud and depletion of the cloud by deposition on the ground. The deposition of material was calculated using deposition velocities that vary with particle size, density, and wind speed. A source depletion model was used to account for reduction in the airborne mass resulting from deposition. These models are used for both the base case in which the Object

Shelter collapses before completion of NSC construction and the case in which the NSC collapses on to the Shelter during NSC sliding.

Radioactive material deposited on the ground was transported by surface water and ground water to drinking water sources and agricultural production areas of Ukraine. Ukrainian eating and drinking habits were utilized to compute ingestion doses.

Accident doses to ChNPP workers are dominated by inhalation exposure. The largest dose (47 μSv) to the public occurs to fishermen of the closest reservoirs. All accident exposures are within Ukainian regulatory limits specified in NRBU-97/D-2000

The CEZ has been free of most anthropogenic influences since the 1986 accident, and flora and fauna have flourished in the absence of humans. The most significant environmental impact of NSC construction may likely be the temporary abandonment of breeding territory by birds along heavily used roads. The loss may be as much as 5% of the annual reproduction in the CEZ for selected species. Such losses are expected to be temporary with the resumption of current normal nesting following completion of construction.

V.B. Prevention of Potential Exposure

The traditional probabilistic accident analyses that one would expect to find in a safety analysis report were submitted to the regulators in a Prevention of Potential Exposure Report (PPER). During NSC conceptual design, Ukrainian regulations were revised to incorporate the PPER in to a larger document, the Sanitary Compliance Report (SCR). At the conclusion of detailed design the PPER will be incorporated into an SCR submitted to the Ministry of Health and Sanitation and an Intermediate Safety Analysis Report will be submitted to the State Nuclear Regulatory Committee.

The PPER developed during conceptual design included a preliminary hazards analysis that considered more than 200 hazards. The hazards were binned according to qualitative estimates of frequency, human consequence, and environmental consequence. Those estimated to represent the greatest risk (risk being the product of probability and consequence) were selected for further analysis.

Additional analyses included event tree analyses, fault tree analyses, scenario development, and consequence estimation. Component failure probabilities were based on Ukrainian nuclear power plant experience. The same source term used for the EIA was used for the PPER.

For all accidents analyzed, human health risk is dominated by inhalation exposure. The accident that represents the greatest risk is fire. Seven fires have occurred (and self-extinguished) in the Object shelter since its construction. Accident analyses indicate that risk reduction investments should first focus on worker training for fire prevention.

V.C. Dose Analyses

Two separate dose analyses were performed during conceptual design: construction dose analysis and a deconstruction dose analysis.

The construction dose analysis was based on the same labor estimates used for construction scheduling and construction cost estimation. Worker dose estimates accounted for exposure at work locations and for exposure during transit time to and from the work locations. Effective dose rates (EDR) were developed from extensive radiation measurements, including energy spectra, that have been taken in the Object Shelter, and on monte carlo n-particle (MCNP) modeling. All dose rates were adjusted for source decay from the date of measurement to the predicted construction period.

The most obvious use of the construction dose analysis was to justify the arch assembly in a remote, low EDR, area and then sliding into its final, high EDR, position. Other as low as reasonably achievable (ALARA) recommendations included installation of local shielding, maximization of remote construction technologies in high dose rate areas, off-site fabrication of modular equipment, and use of strand jacks for arch assembly to minimize construction work at elevation (where sky shine dominates).

The deconstruction dose analysis was based on the same labor estimates used for developing operating cost. EDR inside the NSC were adjusted for increased exposure that results from removing the Object Shelter roof and increased shine from the NSC arch. The dose analysis was instrumental in technology selection for deconstruction and for location of the control room and other continuously occupied spaces. ALARA recommendations included use of shielded boxes transported by the cranes for work at elevation, extensive use of dust management technologies, and increased use of respiratory protective equipment.

VI. ORGANIZATION OF DESIGN WORK

The conceptual design work was performed by a consortium of three large western companies and a major Ukrainian subcontractor. Work was divided between team members on the basis of expertise.

VI.A Work Locations

A Kempner Trego style analysis was performed to determine the optimum work locations. Bechtel performed most structural design in its San Francisco, California, offices. Electricité de France (EDF) performed most foundation and deconstruction design in its Lyon, Frances offices. Battelle performed most environmental and safety analyses in its Richland, Washington offices. äëä performed most design activities in its Kyiv, Ukraine, offices, and most dose and safety analyses in its Chornobyl, Ukraine, offices.

VI.B Communication

Communication among design team members is vital to success. The difficulty of communication during this design effort was exceptional because of team members' multiple locations; differences in time zones; and differences in language and culture. All design documents (calculations, drawings, and reports) were produced in dual languages, Russian and English. Some personnel exchange was used to facilitate communication across multiple locations. EDF placed one engineer in San Francisco; Battelle placed one engineer in Lyon and one in San Francisco; äëä placed multiple engineers in Lyon and San Francisco. Time zone differences were sometimes utilized to the team's advantage as work was passed forward in time. However, a ten-hour time zone difference requires some off-normal working hours to provide even brief overlap between the teams. Multiple translators were utilized in each location.

VI.C Organizational Lessons Learned

Although email, internet, and advanced telephony technologies enabled adequate coordination of a complex design across several locations, the single-most effective tool for successfully coordinating multidisciplinary design teams was found to be the exchange of personnel. Placing Client staff in design locations would have further enhanced communication and the final design product.

VII. CONCLUSIONS

The conceptual design of the NSC has:

- Demonstrated technical feasibility,
- Estimated capital and operating costs, and
- Engaged Ukrainian regulators.

Issues to be completed during detailed design have been formulated in conclusions of the regulatory authorities. Pursuant to the normative requirements currently in force in Ukraine, the first stage of detailed design provides for development of documents to be evaluated and licensed by the appropriate Ukrainian authorities.

It is time to seek competitive solutions for a detailed design by open international tender and commence construction as rapidly as possible.

ACKNOWLEDGMENTS

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Low Doses of Radiation Reduce Risks *in vivo*

by R.E.J. Mitchel[1]

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Abstract

The "Linear No Threshold" hypothesis, used in all radiation protection practices, assumes that all doses, no matter how low, increase risk. The protective effects of adaptive responses to radiation, shown to exist in lower organisms and in human and other mammalian cells, are inconsistent with this hypothesis. An *in vivo* test of the hypothesis in mice showed that a 100-mGy dose of γ-radiation protected the mice by increasing latency for acute myeloid leukemia initiated by a subsequent large dose. A similar result was observed in cancer prone mice, where a 10-mGy adapting exposure prior to a large acute dose increased latency for lymphomas without altering frequency. Increasing the adapting dose to 100-mGy eliminated the protective effect. In the cancer prone mice, a 10-mGy dose alone, without a subsequent high dose, increased latency for spontaneous osteosarcomas and lymphomas without altering frequency. Increasing the dose to 100-mGy decreased latency for spontaneous osteosarcomas but still increased latency for lymphomas, indicating that this higher dose was in a transition zone between reduced and increased risk, and that the transition dose from protective to detrimental effects is tumor type specific. In genetically normal fetal mice, prior low doses also protected against radiation induced teratogenic effects. In genetically normal adult male mice, high doses induce mutations in sperm stem cells, detectable as heritable mutations in the offspring of these mice. A prior 100 mGy dose protected the male mice from induction of these heritable mutations by the large dose. We conclude that adaptive responses are induced by low doses in normal or cancer prone mice, and that these responses can reduce the risk of cancer, teratogenesis and heritable mutations. At low doses *in vivo*, the relationship between dose and risk is not linear, and low doses can reduce risk.

INTRODUCTION

All current radiation risk estimates and all radiation-protection standards and practices are based on the so-called "Linear No-Threshold Hypothesis" that states that risk is directly proportional to dose without a threshold. This LNT hypothesis is in turn, based mainly on epidemiological data of humans exposed to high doses and dose rates but is considered to also apply at low doses and dose rates, with a two-fold reduction in risk. In humans, risk is measured in three ways. The most important measure is considered to be cancer, but the risk of birth defects and heritable mutations is also considered. The LNT assumption allows radiation dose to be used as a surrogate for radiation risk. However, at low doses the LNT hypothesis is acknowledged to be an assumption, and other dose responses are also possible, including supralinear, sublinear or threshold/hormetic responses. This paper reviews data testing the validity of low dose risk estimates that are based on the LNT hypothesis.

While ultimately the influence of low doses on risk must be measured *in vivo*, it is important to understand the mechanisms underlying any such effects. Experiments conducted in other organisms, or based on human and other cells grown in issue culture can provide such information. Therefore, in addition to *in vivo* data, this paper also presents the results of cellular experiments that indicate the mechanisms that may be involved.

If we consider the potential biological consequences of a radiation exposure to a normal cell, there are three general biological outcomes of DNA damage[1] as shown in Figure 1. When DNA damage is created as a result of one or more tracks of radiation through a normal cell, the cell will attempt to repair that damage. If the repair is successful and the DNA restored to its original state, i.e., an error-free repair, then the cell is also restored to normal. In this case, there is no resulting consequence to the cell and hence no resulting risk. Another possibility is that the cell recognizes that it cannot properly repair the damage, and as a consequence activates its genetically encoded cell death process, called apoptosis. Again, in this case, no risk of carcinogenesis results since

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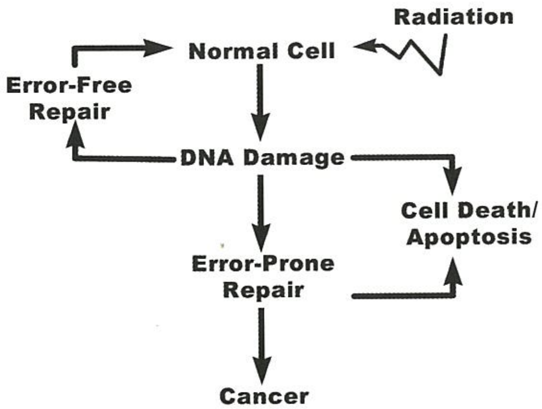

Figure 1. Possible outcomes of a cellular radiation exposure in a normal cell.

dead cells do not produce cancer. However, cell death during embryonic development can lead to teratogenic effects, and so this response is particularly important for that measure of risk. The third possible outcome of the DNA damage is repair that avoids cell death but which is error-prone, resulting in a mistake that creates a mutation. At this point, the cell may still activate its apoptotic cell death program but could also simply resume dividing. Creation of these errors is part of a carcinogenic process called genomic instability, which can ultimately lead to cancer. Errors in the repair of germline cells can lead to heritable mutations, the other measure of radiation risk in humans. It is useful to note that the LNT hypothesis implies that risk is influenced only by dose, and hence predicts that the relative proportions of these three biological possibilities must be constant. If they were not constant, then risk would vary with their relative proportions, and not strictly as a function of dose. Therefore, any biologically induced deviations from linearity would indicate that the LNT hypothesis is invalid.

II EXPERIMENTAL RESULTS AND DISCUSSION

Cellular Studies

A common result of a radiation exposure in cells, particularly a high dose exposure, is a break in one or more chromosomes, which indicate DNA double strand breaks. If cells divide before repairing those breaks, the remaining pieces of chromosomes are packaged into micronuclei (MN). Measuring the frequency of MN in cells that have been exposed and allowed to repair therefore represents a measure of the competence of the cells at repairing such chromosomal breaks (and therefore DNA double strand breaks) in response to radiation damage. We have tested the influence of low doses and low dose rate exposures on the ability of human skin cells to repair radiation breaks in chromosomes[2]. Figure 2 shows the MN frequency in cells exposed to a variety of doses (1-500 mGy) delivered at a low dose rate (3 mGy/min) 3h before exposure to a high dose (4 Gy) delivered at a high dose rate (1.8 Gy/min). The LNT hypothesis predicts that the consequences of the two doses would be additive and yet the experiment shows that they are not. The combined exposure resulted in fewer broken chromosomes than the single acute 4 Gy exposure alone. The figure also shows that enhanced repair occurs after 1 mGy, the lowest γ dose possible in a single cell since it represents, on average, a single track per cell. The figure also shows that higher doses, representing multiple tracks/cell, produce the same result as one track/cell when those tracks from the higher doses are spaced out in time

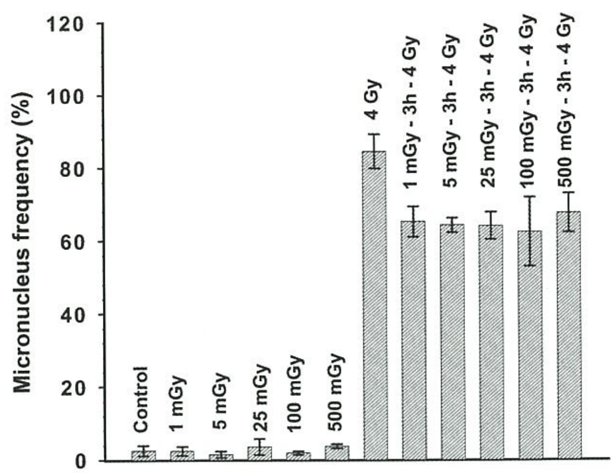

Figure 2. Low doses enhance the repair of broken chromosomes in human cells.

(3 mGy/min). This type of analysis can be applied to *in vivo* situations that have particular importance in the environmental assessment and licensing of nuclear installations. For example we have shown[3] that this adaptive response also occurs in fibroblasts taken from wild white tailed deer, and therefore the consequences of radioactive contamination in the environment may not be as predicted by the conventional LNT assumptions.

A direct test of this idea is shown in Figure 3, which gives some preliminary data[4] obtained from leopard frogs living in either a radiologically clean pond or in a pond contaminated with tritium and ^{14}C that gave an annual dose of about 1 mGy. Liver cells from the frogs living in the clean pond showed a normal adaptive response to low doses, as was seen in the human cells in figure 2. However, exposure of the frogs from the contaminated pond to a large dose produced comparatively little increase in chromosomal breakage in their liver cells, and this was only slightly reduced if the frogs were given a prior low adapting dose.

This lack of chromosomal damage after a high dose indicates that the frogs were already adapted to radiation by their environmental exposure. This *in vivo* measure of the consequences of environmental radiation exposure indicates that low levels of radioactivity in the environment may not be harmful to organisms, and may only serve to enhance cellular defence mechanisms.

Evidence that improvement of cellular defence mecha-

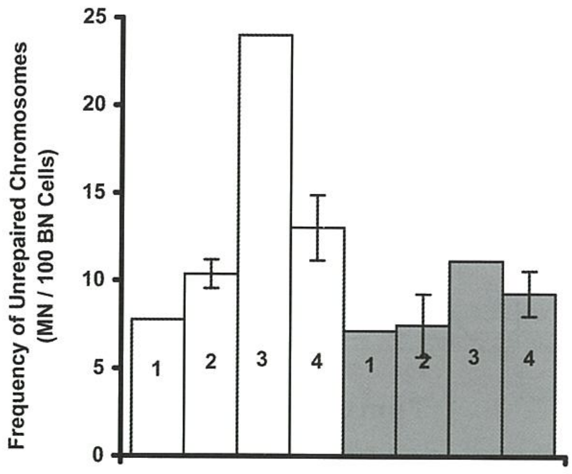

Figure 3. Repair of chromosome breaks in liver cells taken from frogs living in an uncontaminated pond (open bars) or a pond contaminated with ^{3}H and ^{14}C (shaded bars) delivering about 1 mGy/y to the frogs. 1. No further radiation exposure. 2. Frogs receiving 1-100 mGy of ^{60}Co gamma radiation at low dose rate. 3. Frogs receiving 4 Gy of ^{60}Co gamma radiation at high dose rate. 4. Frogs receiving 1-100 mGy at low dose rate 3h before 4 Gy at high dose rate.

Table 1

Treatment	Transformation Frequency (x 10^{-4})
Control	3.7
4 Gy (high dose rate)	41
100 mGy (low dose rate) + 24h + 4 Gy (high dose rate)	16

nisms after low dose exposures is actually reducing cancer risk is shown in Tables 1 and 2. Table 1 shows the results of an experiment[5] using rodent cells and examining the influence of a prior low dose, given at low dose rate, on the risk of malignant transformation resulting from a subsequent high radiation dose. The risk associated with the high radiation dose was reduced by a factor of 2-3 by the prior low dose, a result that parallels the evidence for improved repair of radiation damage shown in Fig. 2.

The ability of a low dose to reduce the risk of a subsequent high dose has importance for medical types of exposures, such as those used in cancer therapy, and for estimates of environmental impact for the nuclear industry. However, the effect of the low dose alone is of more importance for human exposures in the nuclear industry. Table 2 shows the experiment testing the effects of low doses alone on malignant transformation in rodent cells[6]. All the doses tested, between 1 and 100 mGy, given at low dose rate, reduced the risk of spontaneous malignant transformation, and all doses were equally effective. The lowest dose tested, 1 mGy of ^{60}Co γ radiation, represents an average of 1 ionization track per cell, the lowest dose physically possible in one cell. Since radiation tracks are random, not all cells actually receive one track, but all respond to the same extent as they did when they certainly received one or more tracks at the higher doses. This is evidence therefore, that not all cells are actually required to be exposed (hit) by radiation

Table 2

Treatment	Transformation Frequency (x 10-3)
Control	1.8
1 mGy	0.53
10 mGy	0.42
100 mGy	0.53

in order to enhance their defences and reduce their risk. Such distributed effects are known as bystander effects and result from inter-cell signalling.

Cancer Risk in Animals

While experiments in cells provide important supporting information about the actual molecular and cellular responses to low doses, ultimately experiments testing the effect of low doses on measures of risk such as cancer must be conducted in whole mammals. Figure 4 show a test[7] of the influence of a low dose exposure on radiation-induced myeloid leukemia in genetically normal mice. The figure shows that exposure to a high dose of 1 Gy induces myeloid leukemia in mice, and as a result, those mice with the disease lose a substantial portion of their normal lifespan. However, increasing the total exposure, by exposing the mice to 100 mGy, at low dose rate, the day before the 1 Gy exposure delayed the onset of those cancers ($P<10^{-3}$), effectively restoring a portion of the lifespan that would otherwise have been lost in those mice that developed the disease. It is important to note that the low "adapting" exposure did not affect the frequency of the disease induced by the high radiation dose, only the latency. The carcinogenic process is thought to involve an initiating event, which subsequently triggers an accelerating process of genomic instability leading to multiple genomic rearrangements, ultimately producing a cancer cell. The frequency of cancer is thought to reflect the number of initiating events while the latency of the disease reflects the rate at which the genomic instability process proceeds. The results shown in Fig. 4 indicate that low doses delivered at low dose rates slows the rate of progression of the genomic instability process but does not change the frequency of the cancer initiating events[7].

Radiation protection standards and practices applied to humans must consider the possibility that some individuals may be radiation-sensitive and cancer-prone for genetic reasons. This raises the possibility that low doses may produce effects in such individuals that are different, and potentially

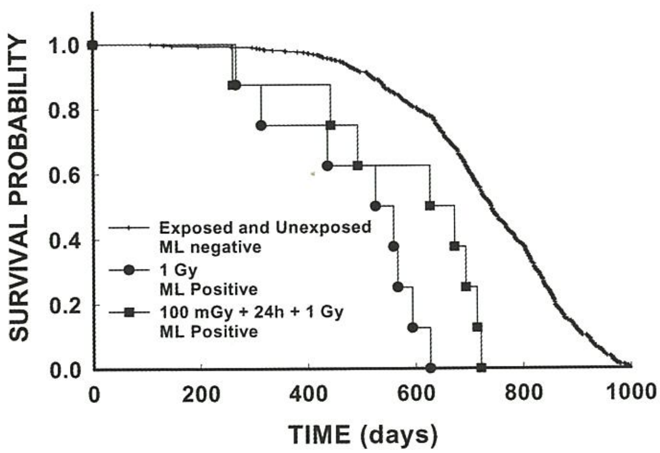

Figure 4. Delayed appearance (P<0.001) of radiation-induced myeloid leukemia (ML) in genetically normal mice by exposure to 100 mGy at low dose rate 24h before the carcinogenic 1 Gy exposure.

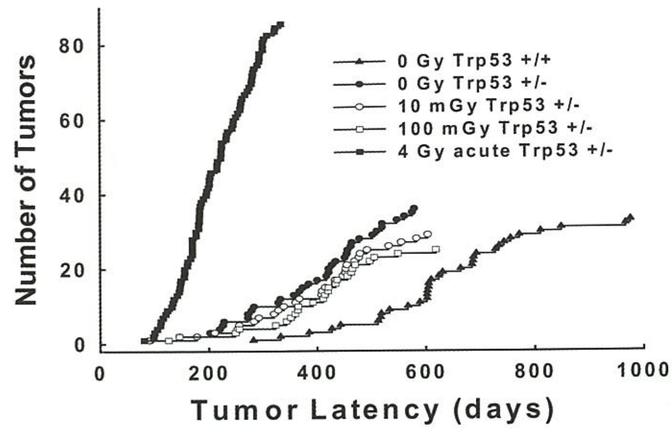

Figure 6. The appearance of lymphomas in unexposed or radiation exposed genetically normal (Trp53 +/+) or cancer prone (Trp53 +/-) mice.

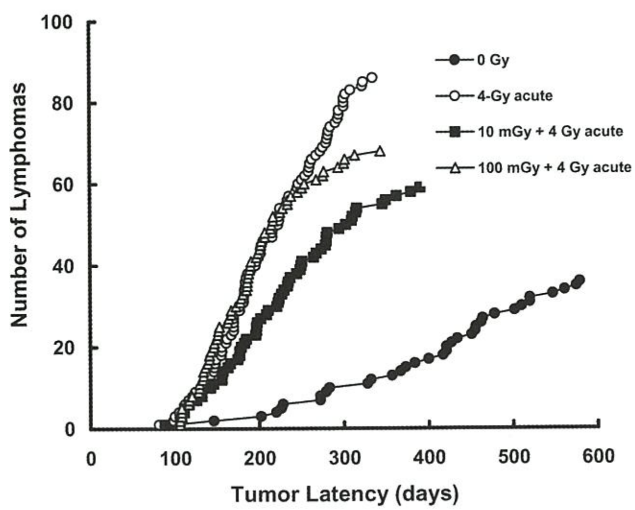

Figure 5. Appearance of lymphomas in unexposed cancer prone mice (Trp53 +/-) and in mice exposed to 4 Gy with or without a prior low dose and dose rate exposure.

more harmful, than those seen in genetically normal individuals. Figure 5 shows a test[8] of this "worst case scenario". Mice that are heterozygous for the p53 gene (Trp53 +/-) are compromised in their ability to repair DNA damage and in their ability to initiate cell death in improperly repaired cells (Fig. 1). Consequently, such mice are both cancer prone and radiation sensitive. Figure 5 shows that these mice spontaneously develop lymphomas, and a high 4 Gy dose of radiation increases the frequency and dramatically accelerates the appearance of these tumours. A dose of 10 mGy, given at low dose rate the day before the 4 Gy exposure delayed the onset of these lymphomas ($P<10^{-4}$), but did not significantly change the frequency. Correcting for competing causes of death did not change this conclusion. This effect of increasing latency was also seen in the genetically normal mice in Fig. 4. Increasing the low adapting dose to 100 mGy caused this protective effect to disappear. While not increasing harm, 100 mGy apparently represents an upper threshold for doses that are protective against radiation-induced lymphomas.

Experiments testing the *in vivo* effect of low doses on cancer risk produced by high dose exposure are important for improving our understanding of the dominant biological outcome of such exposures, and are potentially useful concepts for medical radiotherapy procedures. However, for radiation protection standards and practices in the nuclear industry, it is more important to understand the influence of low doses on spontaneous cancer risk. Figure 6 shows the results of such a test[9] in the cancer prone p53 heterozygous mice that represent the "worst case scenario". The figure shows that unexposed, genetically normal mice (Trp53 +/+) of this strain also spontaneously develop lymphomas but that these cancers appear much earlier in the unexposed, cancer prone (Trp53+/-) mice. Exposure to an acute 4 Gy dose of radiation dramatically accelerated this appearance. The figure also shows that a single exposure of either 10 or 100 mGy, given at low dose rate to young mice, restores a portion of the lifespan lost due to the disease in the unexposed, cancer-prone mice ($P<10^{-4}$). Unlike the result in Fig. 5, where the lymphomas developed in mice that had subsequently received a high dose, the protective effect against these spontaneously appearing cancers was not lost when the dose was increased to 100 mGy. This result suggests that the upper dose threshold for protective effects varies with the severity or nature of the cancer-inducing event, with the threshold being higher for less severe inducing events such as spontaneous occurrences.

Other tumours also appear spontaneously in these cancer-prone mice. Osteosarcomas develop in the spine and grow to the point where they create paralysis in the mice. Figure 7 shows the time that these spontaneous cancers create

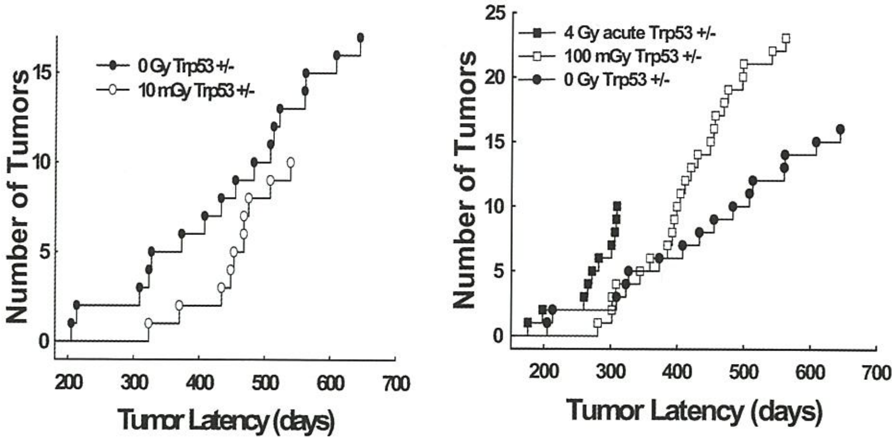

Figure 7. The appearance of spontaneous osteosarcomas in unexposed cancer prone mice (Trp53 +/-), or exposed to 10 or 100 mGy at low dose rate. Exposure to 4 Gy shown for comparison.

paralysis in the mice, with and without a single exposure to 10 mGy given at low dose rate when the mice were 8 weeks old[8]. Compared to the mice not receiving the low dose, the appearance of the first spinal osteosarcoma was delayed by more than 100 days, and that delay persisted for all of the tumours that appeared, i.e. for the entire lifespan of the mice (P=0.005). This lifetime protection was also apparent for the spontaneous lymphomas shown in Fig. 6. However, unlike the case for spontaneous lymphomas (Fig. 6), increasing the low dose to 100 mGy resulted in a general acceleration of the appearance of the spontaneous spinal osteosarcomas (P<0.04, Fig. 7). This decrease in cancer latency clearly represents an increase in risk, rather than the risk decrease seen at 10 mGy. For this tissue type therefore, the upper threshold for protective effects of a low dose must lie between 10 and 100 mGy. Since, in the same animals, the upper dose threshold for protection against lymphomas exceeded 100 mGy, we conclude that the dose threshold, where protective effects give way to detrimental effects, is tissue-type specific.

III. CONCLUSIONS

This paper has described experimental tests, at the molecular, cellular and whole animal levels, of the validity of the Linear No-Threshold Hypothesis at low doses and dose rates. Using a variety of endpoints, some surrogate for risk estimates and others direct measures of cancer risk *in vivo*, the hypothesis has failed at all levels. The LNT hypothesis states that risk per unit dose is constant without a threshold; i.e. that risk is additive and can only increase. The results in cells and *in vivo* show that risk decreases, rather than increases with increasing dose. This reduction in risk below the spontaneous risk level is also not linear with dose. The decrease appears to reach a maximum with the first track of radiation through the cells, i.e. at the lowest dose physically possible in a cell, and stays at that level until the dose reaches about 100 mGy where risk then rises above the spontaneous level. These results indicate that at low dose rate, the assumption of linearity may be valid only at doses above about 100 mGy (with some variation in different tissue types), and below this level radiation-induced protective effects dominate risk. The results in human and other mammalian cells, and in whole animals, described here parallel earlier observations in lower organisms, indicating that these adaptive responses to low doses are not unique to mammals but are part of an evolutionarily conserved response. These protective responses appear to dominate even in individuals that are radiation sensitive and cancer-prone for genetic reasons.

Since radiation exposures in the nuclear industry are overwhelmingly in this low dose and low dose rate region, these results should be considered for their implications for radiation protection and industry practices. In particular, the use of the LNT hypothesis for risk estimation at low doses should be reviewed.

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Sustaining Improved Performance at Bruce Power

by R.E. Tout[1], Raidis Zemdegs, Jordan Chou[2]

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Abstract

Bruce Power (Bruce Power now operates the Bruce Nuclear Plants which were once part of Ontario Hydro) and all of the Ontario Hydro nuclear plants embarked on a comprehensive improvement program in the late 1990's to revitalize the performance of its nuclear units and to implement the necessary programs to sustain these improvements. The improvement program included many initiatives in Engineering, Inspections, Training, Maintenance and Operations.

The objective was to "fix the plant" and then maintain and sustain the nuclear units in a safe and reliable state. This paper will examine the results from a program that began four years ago under OPG and is currently being carried on by Bruce Power. The paper will address those specific aspects of the improvement program whose objective is to continuously assess (System and Component Surveillance program) the material condition of the plant; prescribe and execute timely Preventive and Predictive Maintenance, and implement effective Aging and Life cycle management programs.

I. Introduction:

The Bruce Nuclear Power Development (BNPD) consists of Bruce A and Bruce B. As a result of the Ontario government program to partially privatize electricity generation in the province, Bruce Power signed a long-term lease with Ontario Power Generation in May 2001 and assumed operation of the Bruce Nuclear Power Development. Both stations are four unit CANDU plants. Bruce A has not been operational since 1998, units 1 and 2 are laid up, and unit 4 was returned to service on October 7, 2003, followed by Unit 3 on January 8, 2004. Bruce B comprises 4 x 850MW CANDU units, which have operated with a high level of reliability since the formation of Bruce Power.

The challenge to operate the Bruce B plant at mid-life, safely and economically while undergoing significant program improvements to achieve industry standards was to integrate the results of the improvement initiatives (programs) and optimize the plant material condition while addressing the life cycle and aging management issues. This paper will specifically address the integration of the engineering and maintenance programs and strategies to maintain an optimized plant material condition, which facilitate an effective life cycle management program.

II. Plant Material Condition And Improvement Initiatives:

A unique feature of CANDU plants when compared to PWR units is that the CANDU plant has 25-50% more components. Therefore it becomes important to screen and evaluate how the components are managed and maintained in cost effective manner. All components are not safety -related, and many of the non-safety related components have led to unplanned capacity loss factors (UCLF) which have been significantly higher for CANDU plants than other plants in the world. Based on the nuclear performance review (12 month rolling average) the CANDU median UCLF was 4.7% while the WANO world median was 1.4%.

After the major review (Integrated Independent Performance Assessment) of Ontario Hydro's nuclear program (including the Bruce Power units) in 1996 a comprehensive improvement program (several hundred million $) was approved to return the nuclear units and their operation to a high industry standard. Many projects utilized

1 Bruce Power, Kincardine, Ontario

2 Canadian Nuclear Utility Services, Oakville, Ontario

external expertise and the results and methodologies of nuclear power user groups such as EPRI. The resulting 66 improvement initiatives were categorized as follows:

- Training (authorized operator and nonlicense training)
- Environmental Qualification (licensing condition)
- Conduct of Operations
- Conduct of Maintenance
- Preventive Maintenance
- Engineering
- Safe Operating envelope
- Configuration Management Restoration
- Fire Protection
- Hazardous Materials Management

The initiatives which were directly associated with the plant material condition and associated with life cycle management were:

III. Engineering Programs

- Power Operated Valve Program
- Check Valve Program
- Relief Valve Program
- Heat Exchanger Program
- Pipe Wall Thinning Program
- Plant Thermal Performance Program
- Bolted Connection/Leak Reduction Program
- Electrical Distribution System Analysis

IV. Maintenance And Aging Management Programs:

- Predictive Maintenance Program (Vibration, Thermography and Lubrication)
- Aging Management
- Preventive Maintenance Optimization and Maintenance Living Programs
- Component and Performance Engineering

With this many improvement initiatives under way on an operating plant, there is always a risk of duplicating effort and developing conflicting criteria and requirements. At the heart of the integration and implementation a "Plant Assessment Process" was identified to screen plant structures, equipment and their significance, functions, performance, aging issues and life cycle management. See figure 1.

V. Plant Equipment Assessment Process:

Once the initial screening had defined the "critical" equipment and their attributes, a process was developed to integrate and document all of the results of the many engineering, maintenance, and aging management programs. The resulting reviews and implementation decisions were managed by an expert panel process. Please see Figure 2.

VI. Overall Assessment And Reconciliation Process

In summary, the Reconciliation Process collects and integrates the results of the many improvement programs, utilizes the most knowledgeable plant expertise and dispositions and documents decision for implementation and life cycle management. Some of the outcomes of this process include:

- Categorizes the system components/equipment based on a uniform set of criticality definitions
- Defines the system functions and critical components to each function critical to plant safety and reliability
- Defines function failure modes of this equipment
- Defines aging and degradation modes
- Identifies the most cost-effective maintenance strategy for this equipment (PM, Predictive Maintenance task, Test, Inspection or Run to failure (RTF))
- Provides a documented technical basis for each of the approved maintenance tasks
- Updates the Master Equipment List
- Updates System Performance Monitoring Plan (SPMP)
- Documents repair versus replace decisions
- Evaluates and consolidates Maintenance, Operating histories and Operating Experience from other utilities, EPRI recommendations, licensing and "mandated" requirements.

VII. Component Categorization

For each "critical" component, an analysis determines its function, safety significance, consequence of failure to perform that function.

As a means to "bin" the components, a traditional set categories were used, namely:

- Category 1 – very safety significant / large impact on production
- Category 2 – safety significant / impact on production
- Category 3 – more cost effective to maintain equipment rather than to let it run to failure
- Category 4 – run to failure, corrective maintenance only

VIII. Maintenance Strategy

For each Category 1, 2 and 3 component, an optimum maintenance strategy was developed to consider cost effectiveness, aging mechanisms, surveillance programs etc.. The maintenance strategy for category 4 components is to run the component to failure. However this does not mean the component should remain failed. The component

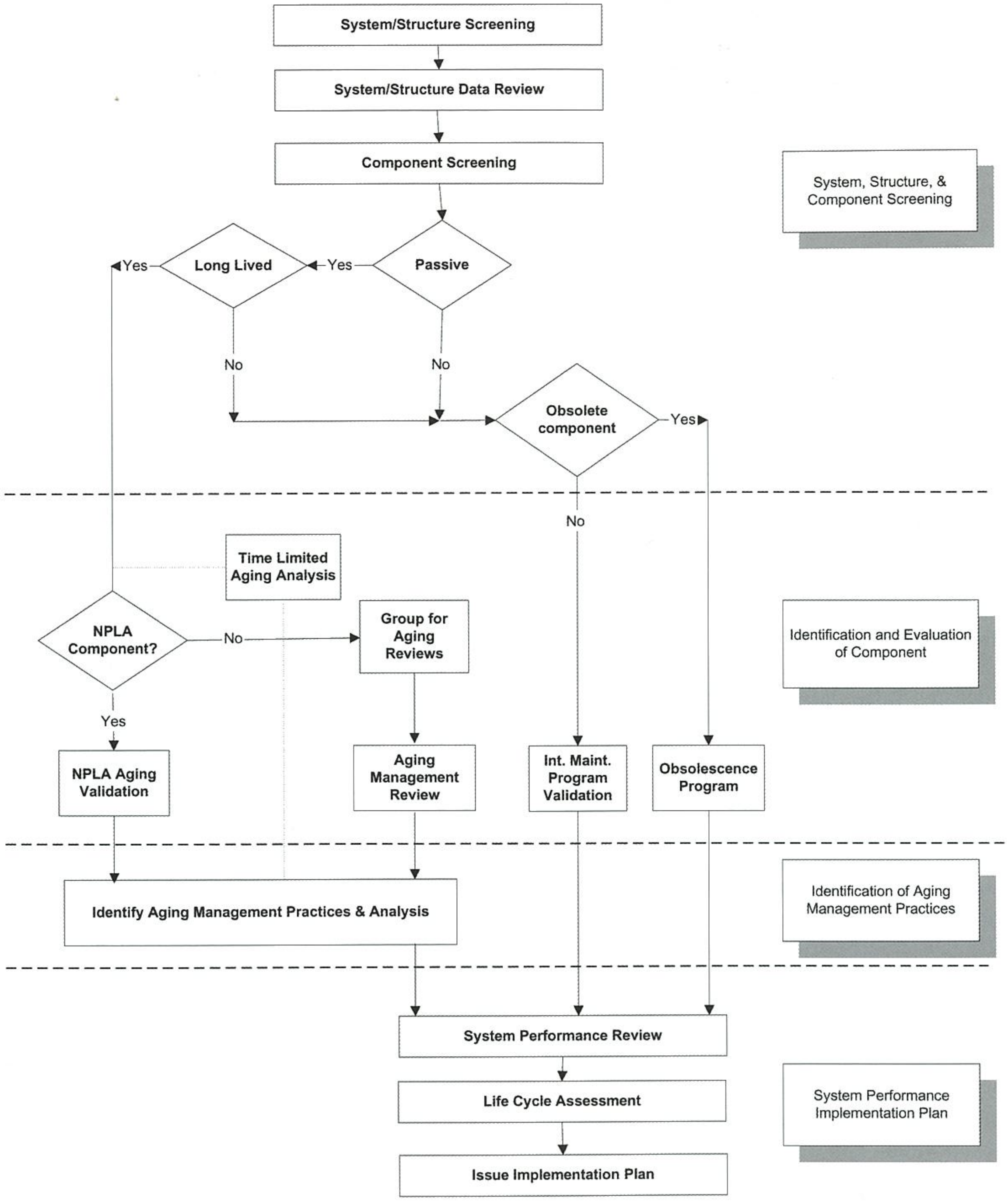

Figure 1. Integrated Plant Assessment Process – Process to screen plant structures, equipment and their significance, functions, performance, aging issues and life cycle management.

categorization is a prioritization process for maintaining equipment in operating condition, not for corrective maintenance. There is an assumption in that all components that fail are repaired promptly or replaced. In defining a proposed maintenance strategy, extensive reviews are made of current and past preventive maintenance histories, operating experience.

The most common maintenance strategies as a result of the review were:

- Time-based predefined maintenance
- Predictive maintenance
- Condition-based maintenance.
- Run-to failure (maintain when failed)
- Replace at time of failure

Scheduled predefined maintenance accounts for much of the preventive maintenance program the project is putting in place. The improvement programs identified predictive

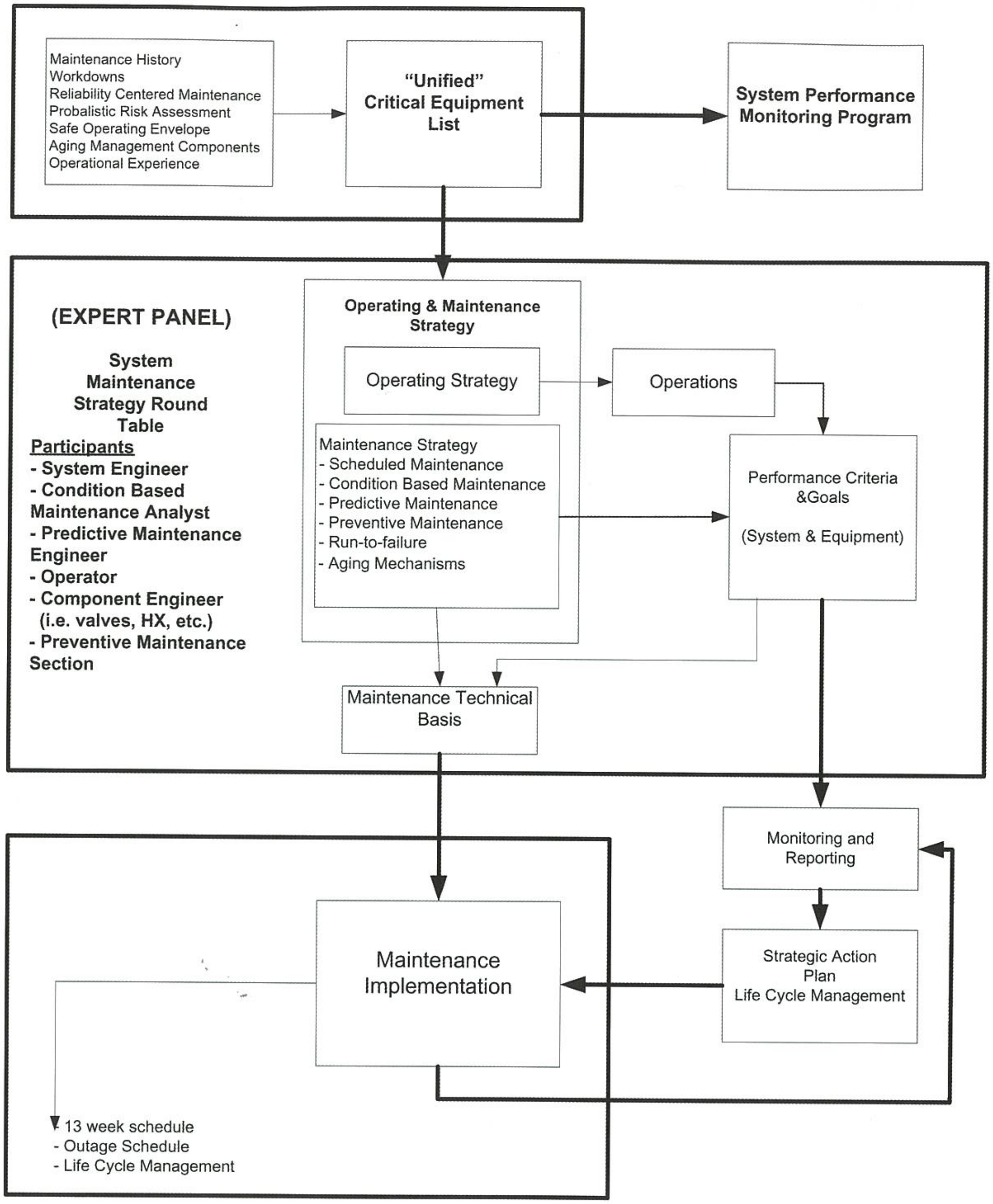

Figure 2. Plan to Reconcile System Performance Monitoring and Maintenance Engineering
The investment addressed major issues

maintenance technologies (supplemented with EPRI experience) where appropriate, including defining a whole infra red thermography program for the electrical systems.

Condition-based maintenance in some cases was the optimal process as the component was maintained only deterioration was detected. Many forms of condition-based monitoring were evaluated and recommended as an overall strategy, including safety system tests (SSTs), operator field inspections (OFIs), comparison of similar monitoring parameters, component and system surveillance programs, and any other program or routine that provides information about component condition. Condition monitoring and predictive maintenance tasks were identified as the best maintenance strategies for components based on operating experience derived from station staff in an expert panel. A future refinement of the allocation of maintenance strategies could utilize mathematical analysis of recorded station experience.

IX. Replace Versus Repair:

In addition to standard maintenance solutions, Bruce Power also evaluated the cost effectiveness to replace components versus repairing them and thereby determine and revise spare part inventories and requirements.

Typically, components requiring corrective maintenance are being repaired. However it can be more expensive to the company to repair a component than to discard it and replace it with a new component. This strategy considers whether there is a benefit from discarding the component and replacing it with new if it requires maintenance. The strategy also considers if there is a benefit to maintaining a swap-out spare component to replace a component needing maintenance, which is then repaired off-line.

X. Other Aspects Of The Maintenance Optimization Reconciliation Project:

There were many other results which were derived from this integrating process, some of which were:

- Maintenance procedures necessary for the specified maintenance strategy are reviewed. These are either determined to be fit for purpose, or necessary changes are identified and carried out through the normal procedure change process.
- Condition monitoring and aging program requirements
- Some of the expert panel meetings generate ideas for design changes. The project evaluates these and if the results stand up to scrutiny, the evaluation is sent on to the engineering design change process.
- Many preventive maintenance activities require spare parts. If the recommended maintenance activity is new or significantly different from those undertaken previously, this may alter the spare parts required for maintenance. In order to obtain the necessary spare parts, an up-to-date bill of materials is required. Any changes to bills of materials required to implement the maintenance strategies is identified and the bills of materials are revised or created as necessary.
- Information on the suggested number of spare components coming from the 'Replace versus Repair' review by the expert panel is passed to inventory management.
- Document configuration issues arise during analysis and at the expert panel. These identify inconsistencies between drawings, design manuals and our master equipment list (MEL) in PASSPORT. These issues are recorded and rectified through the normal change processes.
- All aspects of the recommended maintenance strategies are reviewed to determine if they identify any unique training requirements that are not currently available.

XI. Project Results:

- The full benefits of the Bruce B Maintenance Optimization Project will not be achieved until all the maintenance strategies identified by the project are implemented in the field.
- Overall the amount of Preventive Maintenance "work" has been reduced by approximately 10-20 %. (Ineffective PM has been removed)
- In some cases Bruce Power had omitted PM for critical components (EP provided a systematic process to review, evaluate and correct these situations)
- Where applicable, more effective maintenance (smarter and or proactive maintenance) is replacing more expensive and less effective maintenance. Some scheduled (outage) maintenance is being replaced by less expensive more technically effective condition-based or predictive maintenance.

A total of 200,714 components have been analyzed and categorized. There are a total of ~250,000 components in Bruce B. The fuel handling systems will be the subject of a separate study, and a few minor systems were excluded from the Project. (All components excluding Fuel Handling and other auxiliary systems)have been analyzed and categorized The total number of Bruce B components assigned to each category is given in the following table.

Component Criticality Category	Number of Components in Category
1	8,172
2	26,110
3	23,205
4	143,227

The preventive maintenance strategy for all 143,227 category 4 components is to provide no preventive maintenance, and to operate the components until they require corrective maintenance. All category 1, 2 and 3 components have a defined preventive maintenance strategy agreed through the expert panel process.

The maintenance strategies identified from the Bruce B Maintenance Optimization Project, and agreed by the system expert panels, are summarized as follows.

- 40,787 components have a preventive maintenance strategy that in part or in total utilizes time based predefined maintenance. To achieve this strategy a total of 15,832 predefined changes have been identified by the Project.
- 3,771 components have a preventive maintenance strategy that in part or in total utilizes predictive maintenance. IR thermography will be used to monitor 2,924 components, 709 components will be subject to vibration monitoring, and lubricant analysis is a requirement for 138 components.
- 20,031 components have a preventive maintenance strategy that in part or in total utilizes condition based monitoring. Many forms of condition based monitoring are claimed but the main ones are SSTs (7,182 components), OFIs (2,422 components), Control Room indication and comparative monitoring (8,993 components).

Some category 1, 2 and 3 components have a maintenance strategy that includes preventive maintenance under more than one of the above categories, for instance there is some electrical equipment that is still scheduled to receive periodic overhauls even though IR thermography will also be carried out.

For each component the component category, the criticality analysis description, and an outline of the type of preventive maintenance are loaded in to the Bruce Power PASSPORT system so that they are accessible to all employees to view.

The full implementation of the strategy also requires the up date of the PASSPORT predefineds for time based preventive maintenance, the Odyssey database that drives the companies predictive maintenance program, and any items (e.g. SSTs and ORs). The largest of these tasks is implementation of the predefined changes. At the beginning of September 2003 a total of 4,571 predefined changes had been implemented (35%).

At the beginning of January 2004 ~ 10,000 predefined changes had been implemented (~65%).

The replace v repair strategy has been determined for 10,195 major cat IDs. Of these, components for 5,824 cat IDs should be replaced and discarded if they require corrective maintenance. For a further 904 cat IDs a swap out spare component should be held so that on failure the component can be replaced and repaired off-line. The replace v repair strategies have also been loaded in to PASSPORT.

XII. Project Benefits:

The main benefit resulting from the project is having a defined maintenance strategy in place for station components that has a sound technical basis. This is now defined for 200,714 Bruce B components, and the detailed implementation of the maintenance strategy for these components is well under way. This defines and documents 'the right maintenance' for these components, and addresses the main aim of the project.

In Figure 3 an illustrative total cost for Bruce B maintenance for the year 2002 is given, split in to the main types of maintenance work.

XIII. Conclusions:

The Bruce B Maintenance Optimization Project has put in place a reasoned, technical basis for a maintenance strategy to sustain the plant material condition for most of the components on the four-unit CANDU station.

Bruce Power units continue to enjoy an excellent capacity factor and a relatively low UCLF. However, the greatest benefit of the investment and implementation of the improvement program is to ensure the continued high performance of the plant as it moves from mid-life to end of life. The time scales of many maintenance activities are measured in years, so over the next few years as the benefits of the soundly based maintenance program are felt by the plant, it is expected the current capacity factors should be maintained and improved with regard to maintenance induced outages.

The Preventive (all inclusive forms of noncorrective and replacement maintenance)

Maintenance for 2002 was approximately 22m$. Bruce power has targeted a reduction of these costs by 25% by 2005, by selecting the optimized strategy for component life cycle management and maintenance, while maintaining high capacity factors and low UCLF.

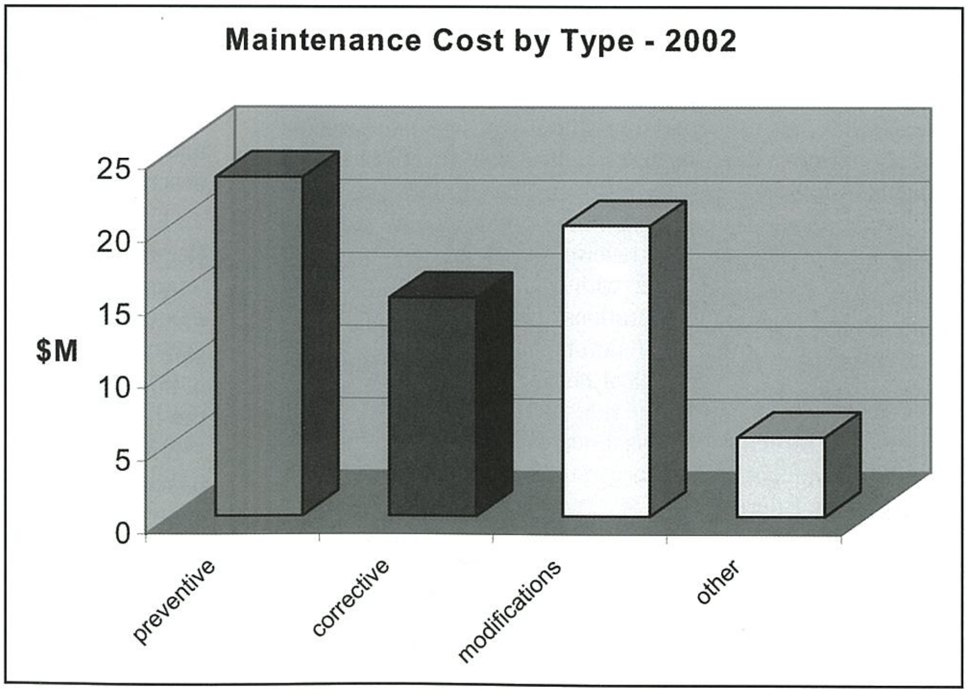

Figure 3. Illustrative Maintenance Spent by Maintenance Category in 2002

Update on AECL's Spent Fuel Management Activities

by M.E. Stephens, D.W. Marinacci, S.K. Cotnam, W.C. Kuperschmidt[3]

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Abstract

AECL continues to contribute to the technology and implementation of spent fuel management in Canada and internationally. This paper describes selected recent examples, which range from construction of large operating facilities to basic research and technology development.

AECL designs and builds CANDU spent fuel dry storage facilities worldwide. AECL has constructed eight large-scale above ground dry storage facilities for CANDU spent fuel in several countries. These projects add up to a constructed capacity in excess of 5,000 MTHM, which is a significant share of the total worldwide dry storage capacity.

With the creation of the Nuclear Waste Management Organization, Canada is progressing towards selecting and implementing an approach for the long-term management of Canada's nuclear fuel waste.

AECL continues its research on deep geological disposal of spent nuclear fuel under Ontario Power Generation's Deep Geologic Repository Technology Program. AECL's contribution builds on the experience gained at AECL's Underground Research Laboratory (URL) facility near Whiteshell Laboratories over the last 20 years.

AECL's global waste management experience includes its collaborative projects with other countries, including Sweden, Finland, and the United States. A recent example is the current second phase of the Tunnel Sealing Experiment on repository seal technology, which is funded by France and Japan and is now being brought to a close with the planned decommissioning of the URL.

AECL continues to support the U.S. Yucca Mountain project. Recent technical work encompasses radionuclide transport experiments, crevice corrosion studies on waste package components, and extensive independent reviews of scientific documentation pertaining to the suitability of Yucca Mountain as repository for the disposal of high-level nuclear waste.

I. Introduction

AECL's extensive waste management activities over several decades have included operation of waste management storage and processing facilities at its Chalk River (CRL) and Whiteshell Laboratories (WL); operation of the Low-Level Radioactive Waste Management Office (LLRWMO) on behalf of Natural Resources Canada to resolve historic radioactive waste problems (largely associated with radioactive ore recovery, transport and processing operations) that are the responsibility of the Federal Government; development of the concept and related technology for geological disposal of Canada's nuclear fuel waste; development of the IRUS (Intrusion-Resistant Underground Structure) disposal concept for low-level nuclear waste; development of dry storage technology for interim storage of used fuel; development and assessment of waste processing technology for application in CANDU nuclear power plants and at CRL and WL. A comprehensive picture of AECL's waste management activities was presented at Spectrum 2002[1].

AECL's recently introduced corporate vision includes the goals of protecting the health and safety of the public, our employees and the environment, and minimizing nuclear legacy obligations for future generations. AECL's continuing commitment to the resolution of nuclear waste management issues in Canada and internationally directly supports these goals. This paper describes some of AECL's recent activities in this area.

II. Interim Storage Of Spent Fuel

The Canadian strategy for managing the used fuel from Canada's CANDU® nuclear power plants has been to provide safe interim storage at the reactor sites using a combination of pool and dry storage technology, and in parallel to develop the technology for disposal.

Both pool and dry storage of spent fuel are fully proven, based on many years of successful, safe operating experience. AECL pioneered the dry storage concept in Canada, and has now completed dry storage facilities for both domestic and foreign utilities.

1 Atomic Energy of Canada Limited, Chalk River, Ontario

Figure 1. Basket Holding 60 CANDU Spent Fuel Bundles

Table 1: CANDU Dry Storage Facilities In Operation

Location	Fuel Quantities	Number of Canisters/ Modules
WL	17 MgU	11
Gentilly-1	67 MgU	11
Douglas Point	298 MgU	47
Nulcear Power Demonstration	75 MgU	11
Pt. Lepreau	2790 MgU (lifetime)	275 (lifetime)
Wolsong-1	2790 MgU (lifetime)	275 (lifetime)
Gentilly-2	2790 MgU (lifetime)	16 modules
Cernavoda 1-2	6156 MgU (lifetime)	27 modules

When a CANDU natural uranium fuel bundle is discharged from the reactor after 12-18 months of irradiation, it is removed to a pool system for interim storage. The water in the pool removes the residual heat produced by the spent fuel and provides radiation shielding for workers. The compact design of the CANDU fuel bundle, and the impossibility of criticality occurring for CANDU natural uranium spent fuel bundles in water pool storage, make for extremely simple and economical pool storage. Fuel packing densities are determined by considerations such as heat transfer and shielding and not by the need to avoid criticality accidents.

After spent CANDU fuel has been out of the reactor for about six years, its activity and rate of heat generation have decreased sufficiently to allow the fuel to be transferred to dry storage, if desired. Compared with wet storage, dry storage is considered to have the following advantages: safe and passive storage conditions, ease of expansion, simplicity and low construction and operating costs.

AECL started to study dry storage for spent nuclear fuel in the early 1970s. Silo-like structures called concrete canisters were first developed for the storage of enriched uranium fuel from research reactors and were then further developed for spent CANDU natural uranium fuel. By 1989, concrete canisters were being used for safe and economical storage of all spent fuel accumulated during the operation of AECL's decommissioned prototype reactors (see Table 1). Each concrete canister contains a stack of spent fuel baskets, illustrated in Figure 1.

The same basic technology was then applied to on-site dry storage of spent fuel generated by operating CANDU nuclear power generating plants. New Brunswick Power and Korea Electric Power Company selected AECL's concrete canister technology for their CANDU 6 nuclear generating stations at Point Lepreau (1989) and Wolsong 1 (1990) (see Table 1).

In 1989, AECL began development of a monolithic, air-cooled concrete structure for dry storage, called MACSTOR. A full scale test facility was built at AECL's Whiteshell Laboratories that confirmed the efficient thermal performance. MACSTOR modules require less land area than concrete canisters for the same amount of spent fuel. They are suitable for storage of spent fuel assemblies from CANDU reactors as well as other reactor types (PWR, BWR, VVER and RBMK) and can be deployed in very compact storage sites, as depicted in Figure 2.

The AECL process for dry storage of CANDU fuel consists of loading fuel bundles in fuel basket (in the pool), drying, welding and examination in a Shielded Work Station and includes final transfer of spent fuel baskets and their emplacement in the concrete storage structures using a transfer flask.

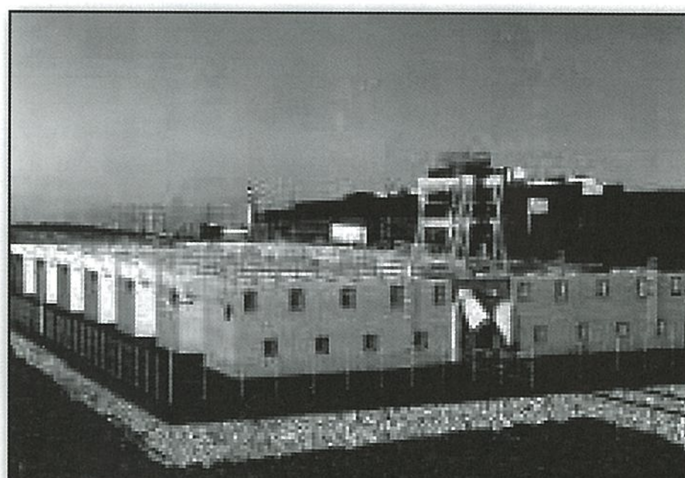

Figure 2. MACSTOR Dry Storage Module Site

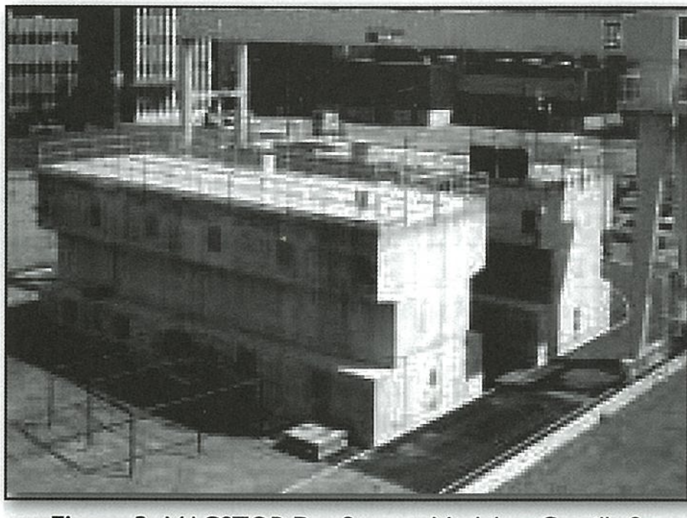

Figure 3. MACSTOR Dry Storage Module—Gentilly 2

Figure 4. The Cernavoda MACSTOR Dry Storage Facility in Romania

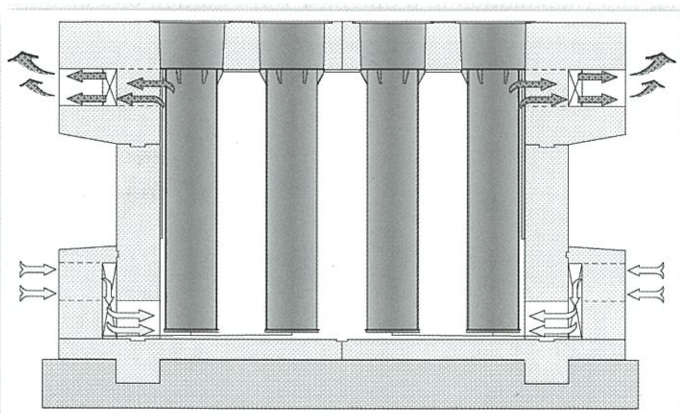

Figure 5. The MACSTOR/KN-400 for Wolsong 1-4 Reactors (Korea)

In 1995, Hydro-Québec built the first MACSTOR system for dry storage at the Gentilly-2 CANDU 6 nuclear generating station (see Figure 3).[2]

In 2000, the Romanian company *Societatea Nationala Nuclearelectrica S.A.* (SNN), the plant owner of the Cernavoda station, proceeded with an international bid for the supply of dry storage technology for spent fuel from Unit 1 (and eventually Unit 2) of the Cernavoda CANDU 6 nuclear power plant. The MACSTOR system emerged as the most suitable and cost effective technology. AECL has supplied the complete spent fuel packaging system and dry storage structure, including the construction of one storage module (see Figure 4). The project started in 2001 and was completed in 26 months with first spent fuel loaded in June 2003.

Since 2001, KHNP/NETEC (K/N) and AECL have been jointly developing a higher-capacity dry storage structure based on the MACSTOR storage module concept for the Wolsong site. The proposed approach addresses the conditions that are specific to Wolsong: large yearly fuel throughput, space limitations, and the need for an economical dry storage structure that can store lifetime spent fuel inventories expected from the four CANDU reactors.

The selected configuration is a 4-row MACSTOR-like module with a capacity of 24,000 bundles stored in 400 baskets, each holding 60 spent fuel bundles (see Figure 5). The module is thus termed MACSTOR/KN-400 and is expected to offer a repetitive storage density increase by a factor of about 3, compared to concrete canisters that are presently in use.[3]

III. Long-term Management Of Spent Fuel

Current spent fuel storage practices have an excellent safety record at CANDU sites, permit easy monitoring and retrieval, and could be continued for many years. Storage, while an extremely effective interim measure, is not considered to be a permanent measure. Canada and other countries with nuclear power programs have for many years been developing the technology for the disposal of nuclear fuel waste. Disposal is considered to be a permanent solution for the long-term management of nuclear fuel waste since it relies on passive safety and does not require institutional control after closure of the facility. There is international consensus among waste management experts that the preferred method for long-term management of nuclear fuel waste is land-based geological disposal.[4]

In the 1980s and 1990s, AECL developed a concept for disposal of Canadaís nuclear fuel waste based on deep geological disposal, similar to the disposal methods proposed in many other countries.[5]

AECL proposes to use the very stable rock of the Canadian Shield. The waste would be emplaced in a repository excavated in the rock below the water table. The principal concern from the point of view of long-term safety is that groundwater could eventually become contaminated with radioactive or other hazardous materials, and ultimately make its way to the surface and pose a risk to future human health or the environment. The multi-barrier system consisting of the chemically stable waste form, the very long-lived container, the buffer and the rock, provides assurance that the effects will not be significant. Thus, human health and the environment will be protected, even in the very long term.

Considerable efforts have been made internationally to evaluate the behaviour of deep geological repositories with time, as well as their long-term safety. There is an international consensus among waste management experts that "appropriate use of safety assessment methods, coupled with sufficient information from proposed disposal sites, can provide the technical basis to decide whether specific disposal systems would offer to society a satisfactory level of safety for both current and future generations".[6]

AECL has carried out comprehensive quantitative assessments of the risk associated with the AECL disposal concept.[5,7] These analyses indicate that the amount of contaminants moving from a repository to the surface would be very small and that the radiological dose would be many orders of magnitude below that from naturally occurring radioactivity in the surface environment, and even further below that known to cause harm. In 1994 the concept was submitted for an extensive environmental review by an independent panel under the Government of Canada's Environmental Assessment and Review Process. The review included an in-depth technical review of the concept, probably the most extensive technical assessment review of any project ever advanced in Canada.

The panel issued its concluding report in 1998.[8] The report addressed each of the safety criteria and concluded that from a technical perspective, the safety of the AECL concept had been on balance adequately demonstrated for a conceptual stage of development, but from a social perspective, it had not.

The panel concluded that, to be considered acceptable, the concept must have broad public support, be safe from both a technical and social perspective, have been developed within a sound ethical and social assessment framework, have support of Aboriginal people, be selected after comparison with the risks, costs and benefits of other options, and be advanced by a stable and trustworthy proponent and overseen by a trustworthy regulator.

The panel recommendations included the following: that a Nuclear Fuel Waste Management Agency (NFWMA) be established at armís length from the utilities and AECL, with the sole purpose of managing and co-ordinating the full range of activities relating to the long-term management of nuclear fuel wastes; and that governments should direct the NFWMA to develop practical long-term waste management options for Canada, including a modified AECL concept for deep geological disposal, storage at reactor sites, and centralized storage, either above or below ground.

IV. Current Situation

In 2002, the Government of Canada approved the national Nuclear Fuel Waste Act (NFWA).[9] The legislation required electricity generating companies which produce used nuclear fuel to establish a not-for-profit waste management organization to carry out the managerial, financial, and operational activities to implement long-term management of nuclear fuel waste. Accordingly, the Nuclear Waste Management Organisation (NWMO) was established in October 2002, and a president, board of directors, and advisory council were selected. The NWMO is to manage all of the nuclear fuel waste of the utilities, universities, and other small owners in Canada.

As its first major task, the NWMO is to study the options and different approaches for the long-term management of nuclear fuel waste, including geological disposal based on the concept developed by AECL, storage at reactor sites, and centralized storage above or below ground. Other approaches may also be considered. The NWMO also is required to carry out public consultations and to maintain an advisory council whose comments on the NWMOís study and reports are made public. By November 2005, the NWMO must submit to the Government of Canada a study of its proposed approaches for the management of nuclear fuel waste and its recommendation as to which of the proposed approaches should be adopted. The NFWA legislation authorizes the Government of Canada to select an approach set out in the study. The governmentís choice will then be implemented by the NWMO, subject to all of the necessary regulatory approvals.

In its first year, the NWMO has engaged in a series of conversations about expectations with stakeholders, technical experts, and interested Canadians, and it has begun to explore the fundamental issues involved in developing a strategy for long-term management of used nuclear fuel that safeguards the public in a way that is sustainable, ethically and socially acceptable, and respectful of the environment now and in the future. A collection of background papers has been commissioned to present factual information on the current status of nuclear fuel waste and the context for its long-term management. Extensive information on NWMO activities is posted on the NWMO website: www.nwmo.ca.

The NFWA legislation also authorised the establishment of a trust fund by the owners of nuclear fuel waste in Canada to pay for the long-term management of the waste, with deposits to the fund to be made on an annual basis. The NWMO will only have access to this funding after the Government of Canada has selected and approved a long-term management approach and has issued an appropriate licence related to activities for implementation of the approach. On behalf of the nuclear fuel waste owners in Canada Ontario Power Generation (OPG) has continued to provide financial support and technical direction to advance and optimize the disposal technology and to maintain key areas of technical expertise.

Current AECL Activities in Deep Geological Disposal

In recent years AECL has continued performing R&D required to further refine the technology for deep geological disposal under OPGís Deep Geologic Repository Technology Program (DGRTP). The areas of AECL effort include geoscience and methods for site characterization, repository design and engineering, and long-term safety assessment.

Geoscience and site characterization studies have recently covered, for example:

- use of a Geographical Information System-based method for interpreting surface lineaments in relation to local geology;[10]
- examination of fracture minerals and rock alteration as indicators of past groundwater recharge in fractured crystalline rock;[11]
- application of Apatite Fission Track thermo-chronology to

examine the very long term evolution of the Precambrian Shield in eastern Ontario.[12]

Recent repository design and engineering work has included:

- methods for in situ determination of rock stresses during repository siting and construction;[13]
- in situ investigation of the response of tunnel bulkhead seals and surrounding rock to increased temperature;[14]
- engineering analyses to assess the effect of various waste-emplacement methods and sealing-system designs on the long-term thermal and mechanical performance of a repository.

Long-term safety assessment developments include:

- laboratory studies of the effects of £\-radiolysis on long-term dissolution of used CANDU fuel;[15]
- validation tests on the SYVAC system performance assessment code submodels for radioactive decay, used fuel degradation and release of contaminants from a failed fuel container, and on conservation of mass;[16]
- sensitivity analysis of the many-parameter SYVAC code by using Haar wavelet basis functions to construct a response surface with parameter values set by fractional factorial sampling.[17]

Over the past 20 years AECL has carried out R&D in collaboration with the waste management organisations in a number of other countries, including Finland, France, Japan, Sweden, the United Kingdom and the United States. AECL's Underground Research Laboratory (URL) near Whiteshell Laboratories is dedicated to the study of technologies related to the long-term management and deep geological disposal and storage of nuclear fuel waste. For over 10 years, a major experimental program has been undertaken in the URL to develop various technologies that form the basis of the deep geological disposal concept.

A recent achievement was the completion of the first phase of the Tunnel Sealing Experiment (TSX), co-sponsored by AECL, OPG, ANDRA (France), JNC (Japan) and the USDOE.[18] The TSX is a large-scale demonstration of the design, construction and performance of concrete- and clay-based seals simila to those that would be used in a geological repository. Two bulkheads, one composed of high-performance concrete and the other of highly compacted sand-bentonite material, have been constructed in a tunnel in unfractured granitic rock a the 420-m level in the URL (see Figure 6). The results from the TSX have been used to characterize the performance of the two bulkheads under applied hydraulic pressures. The chamber between the two bulkheads has been pressurized to 4 MPa, a value representative of the ambient pore pressures in the rock at a depth of 420 m. Instrumentation in the experiment monitors the seepage through and around each bulkhead, as well as parameters that are important indicators of bulkhead performance.

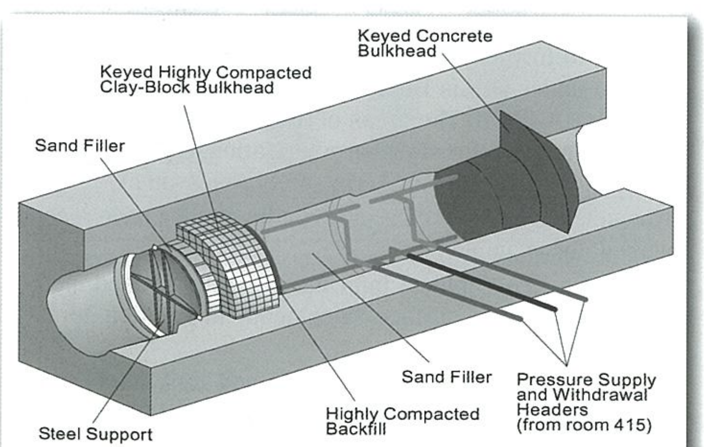

Figure 6. The TSX Experiment

In the second phase of the TSX, supported by JNC and ANDRA, the performance of the two bulkheads is being tested at higher temperatures, comparable to those expected in a geological repository.

In 2003 OPG informed AECL that it would not fund the operation of the URL beyond 2003 June. As a result AECL has initiated a plan to decommission the facility. With the support of ANDRA and JNC, the second Phase of the TSX is being completed on a somewhat accelerated schedule, with TSX underground work to be completed by 2004 May or June. Data from the TSX experiment will be analyzed in 2004.

AECL Participation in DECOVALEX

On behalf of OPG, AECL continues to play an active role in DECOVALEX, an international co-operative series of projects to develop coupled Thermo-Hydro-Mechanical (THM) models and validate them against experiments. The main theme of DECOVALEX III is to examine state-of-science issues surrounding the application of coupled THM models to geoscience problems related to deep geologic disposal.

Bench Mark Task 3 (BMT 3) is concerned with the coupled hydro-mechanical (HM) impacts of one or more cycles of glaciation and deglaciation on the long-term (up to 100 000 years), post-closure performance of the geosphere in which a repository is located.[19] A task force led by AECL developed the case definition, coordinated the modelling work and synthesized the results of the participating research teams.

AECL Supporting Work for the U.S. Yucca Mountain Project

In the United States, AECL has supported the USDOE during the site characterization phase for the construction of a geologic repository at Yucca Mountain, Nevada. Recent AECL contributions include:

- experiments on unsaturated and saturated flow and transport of radionuclides in blocks of tuff excavated from Busted Butte; [20,21]
- experiments to determine whether various combinations of fuel packaging materials would be susceptible to crevice corrosion;
- excavation by wire saw of a block of rock at Yucca Mountain for experiments at Lawrence Berkley National Laboratory to validate several models related to fracture networks;
- extensive independent reviews of scientific documentation pertaining to the suitability of Yucca Mountain as a repository for the disposal of high-level nuclear waste.

V. Summary

AECL has managed spent fuel and maintained an active R&D program in high-level radioactive waste management since the inception of the Canadian nuclear program at CRL.[1]

AECL also continues to support nuclear waste management activities of other nations, including designing and constructing dry storage facilities for spent fuel in several countries, continuing R&D on deep disposal, completing the second phase of the Tunnel Seal Experiment in the URL, and supporting the United States Yucca Mountain deep geological disposal project.

VI. Acknowledgements

The authors thank Robert Beaudoin in the Montreal Engineering Office and Peter Sargent of the Waste Technology Unit at Whiteshell Laboratories for their contributions to this paper, and J. Pecoskie for expert preparation of the manuscript.

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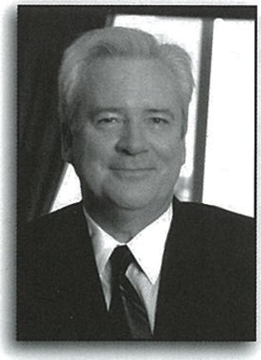
Human Resources at OPG
A Conversation with John Murphy



Prologue: *The 19th floor of 700 University Avenue in Toronto, the executive floor of Ontario Power Generation, is almost empty these days. However, John Murphy, executive vice-president Human Resources, is still there and graciously received us the end of April for a conversation about staffing, training, etc., the whole field of "human resources" at OPG.*

The motivation for seeking the interview was the occasion of the International Youth Nuclear Conference (IYNC) being held in Toronto in mid May 2004. A major question posed by the younger participants in the nuclear industry is what future is there for them. That leads directly to questions about the ageing workforce, plans for recruitment, training, advancement and the general future for nuclear science and technology. Those were questions we wished to pose to John Murphy.

John Murphy came to his current position through a somewhat unusual route. Prior to joining OPG he was president of the Power Workers Union (PWU), which represents most of the non-professionals at OPG and Bruce Power. In that role he had been a member of the Board of Directors of Ontario Hydro and, subsequently, OPG. During that period he served as chairman of the Board of Director's Health and Safety Environment Committee. He was appointed to his current position in May 2000.

Outside of OPG he is a volunteer member of the boards of several organizations, including the ABC Literacy Foundation and the Canadian council for Public Private Partnerships.

John is also Chief Ethics Officer for the company a position he was assigned in March 2002. The role encompasses the preparation of a Code of Business Conduct for Board approval and, with that in place; providing advice on its application; tracking and reporting violations; ensuring appropriate management action; and reviewing the Code on a regular basis.

Following are excerpts from that very interesting conversation.

CNS: How does your background with the PWU affect your current position ?

Murphy: It has given me an additional perspective. My view is that if an organization is managed well and if issues important to staff are being addressed there is no need to work around the union. If people have to resort to the union with grievances then management has failed. Unions can be an additional resource in identifying concerns. Our relations with the PWU and the Society of Energy Professionals have significantly improved over the past few years. One measure is the number of grievances, which now stand at about 140 compared to over 3,000 a few years ago.

CNS: Turning to factual matters, what is the current average age of OPG's nuclear workforce ?

Murphy: The average age of OPG's nuclear staff is now 44 years, down slightly from a couple of years ago due to retirements and voluntary separations.

CNS: What percentage will be eligible for retirement over the next five years ?

Murphy: The best way to answer that is to show you the following tables. The term "eligible for undiscounted pension" refers to those who have accumulated the magic number of 82 when adding age to years of service. You will see that most of those eligible for retirement fall into that category rather than the normal retirement age of 65.

To put these numbers into perspective the number of regular staff at OPG Nuclear at the end of the first quarter of 2004 is 6385. You will

	2004	2005	2006	2007	2008
"eligible for undisounted pension*	370	201	226	218	256
cumulative total	370	571	797	1015	1271
"eligible for normal retirement*	9	13	18	24	33
cumulative total	9	22	40	64	97

"The totals for "undiscounted pension" include those for "normal retirement".

see that about 20 percent of the current staff will be eligible for retirement within five years.

The downsizing that has occurred over the past year has followed a radically different approach from that of the past, especially that of 1993 when the best talent left. In early 2003 we sat down with the two major unions and negotiated agreements for the downsizing primarily of support functions. Those agreements emphasized that severance would be voluntary. The new aspects were that management would select who would receive an offer and it would be phased over two years. The company achieved its objective of a controlled downsizing and the unions ensured that each case was voluntary.

CNS: Earlier Ontario Hydro divested itself of the Bruce site and subsequently OPG has spun off Nuclear Safety Solutions and other groups. How has this impacted on the overall staffing question ?

Murphy In each case we have ensured that the collective agreements would continue. Further we have emphasized communication, communication so that the concerns of individuals would be answered. We have tried to get those involved to focus on the future and the possibilities in the new organizations. It is my impression that most of those affected have been quite satisfied with the change.

CNS: What actions is OPG taking to maintain an adequate level of staffing ?

Murphy: We have a number of initiatives underway, such as strategic hiring programs, an apprenticeship program, and on-going programs with colleges and universities. In that last area we are a major supporter of UNENE (University Network of Excellence in Nuclear Engineering).

This year we have ramped up the hiring of operators-in training and control technicians. Just last week (April 2004) 15 control technicians were hired for Darlington. An additional 60 are sought for Pickering.

In the area of skilled trades Canada in general is facing a bleak future. For its part OPG is working with the PWU in sending speakers to high schools and colleges to emphasize that there is a good living to be made in the trades. In many cases we bring young staff members, who can relate to the younger generation, as speakers. We are working with colleges, especially Durham College [located between the Pickering and Darlington nuclear stations] to understand the wants and needs of the students and, in the case of Durham, have been in discussion with them about their curriculum.

We have found that young people today want employment that is meaningful. There is considerable emphasis now on "employee engagement". That is not just "satisfaction" but more how an individual feels about their contribution to the task. Feeling part of a team is important.

The Globe and Mail [newspaper] has, for the past few years, identified Canada's 50 best employers. We are not in that list but are now using the tools involved and measuring ourselves against the same criteria. We hope that within a few years we will be in the top ranks of that listing.

I believe that we must take a holistic approach. We must market the nuclear industry as a whole as well as OPG as a good company to work for. There is an increasingly tight market for skilled people. In that regard, a significant challenge we are tackling is a review of work processes. It is recognized that there are many inefficiencies in the current system. If these can be addressed it may not be necessary to replace all of those retiring over the next few years.

CNS: Could you expand on that topic of "work processes"?

Murphy: Yes. In particular we are proceeding with a program of "skills broadening" with the full cooperation of the PWU. This will enable a tradesman or technician to work on jobs outside their basic specialty. The program was developed with the union and was implemented by offering the "skills broadening" program for the individual choice of each worker. Almost 100 percent signed up. Individuals will be given the opportunity to learn additional trades and skills. This will enable one person or a small team to do jobs that previously required a series of different trades.

Further, our operations people are installing more discipline into the work processes, with more organization and planning. This should improve the "wrench time" that became quite low in the past. Outages are being planned in detail in advance, including any special training that might be required prior to beginning the operation. Special crews will be formed to tackle unsuspected problems.

CNS: What steps is OPG taking to record, document, transfer corporate memory ?

Murphy: A major initiative is the Configuration Management Restoration Project, which ensures any physical changes in a plant are tied to documentation.

In nuclear operations, where the risk of loss of intellectual capital is greatest, we have recently initiated some grassroots knowledge management programs, which look at the combination of knowledge bases that employees with critical skills possess:

- Explicit Knowledge - for example, data available in research results and data bases, codified and organized information in forms, templates and procedures and codified, unorganized material available in minutes of meetings, notebooks etc.

- Tacit Knowledge: this is knowledge held within the individual -the individual's own expertise.

Ontario Power Generation is just embarking on knowledge management programs. We have completed a risk assessment of the potential loss of knowledge in some key engineering departments and are now actively working on plans to reduce those risks. Several approaches are being pursued including computerized concept mapping and artificial intelligence databases. We are also considering hiring trainees to work with and document information transferred from experts.

CNS: You have mentioned training several times. Is that the responsibility of your Human Resources department ?

Murphy: No. Most of the training is conducted by nuclear operations. They have the people with the knowledge and skills and it is more practical to conduct the training on site and within their particular time constraints.

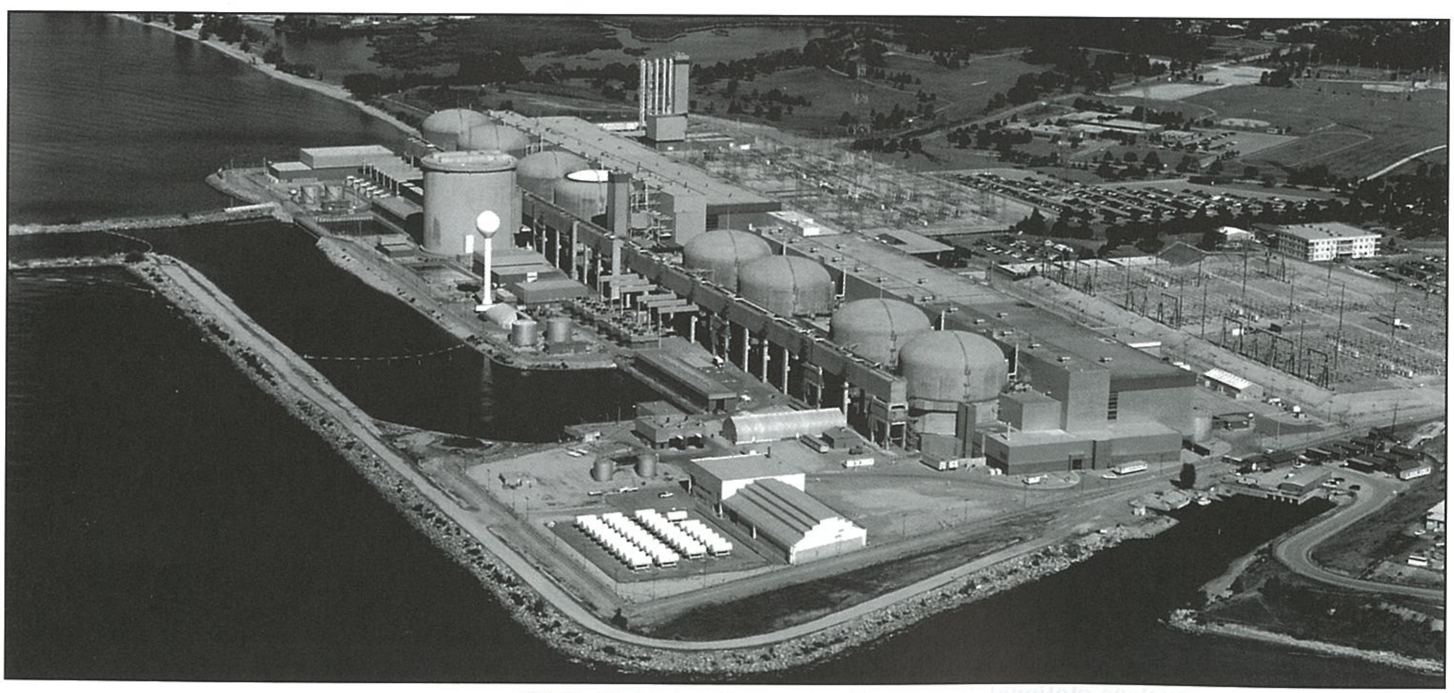
We are continuing specific training in special areas, such as that for operators needing authorization by the CNSC [Canadian Nuclear Safety Commission], which is typically about a seven-year process. In that regard we have not taken an official OPG position on the CNSC requirement for re-certification but will offer appropriate programs for those affected.

CNS: Do you see any role for the CNS in this area ?

Murphy: Yes. The CNS has an enormous opportunity to spread the word about the opportunities in the nuclear field. Significant investments will be needed for our existing ageing plants which will need qualified people and I believe that new nuclear has to be part of our future.

CNS: On that positive note, thank you for this meeting.

Murphy: It was a pleasure. Let us move forward together.



OPG's Pickering Generating Station

25th Annual Canadian Nuclear Society Conference
"Nuclear Energy: Meeting the Challenges"

2004 June 6-9, Marriott Eaton Centre, Toronto, ON

Program Outline as of 2004 May 12 - Titles of papers are shortened for space reasons (see footnote)

Sunday June 6, 19:00-21:00 Conference Reception

Monday June 7

Plenary I The Security of Supply Challenge

08:30 Welcome, J. Whitlock (CNS President) and B. MacTavish (Conference Chair)

08:45 Setting the Scene - The Electricity Market and Ontario's Supply/Demand Situation, D. Rochester (IMO)

09:10 Challenges of Nuclear Life Extension, P. Charlebois (OPG)

09:35 Plans to Meet the Future Supply Challenge, A. Johnson (Bruce Power)

10:00 Break

10:30 Supply/Demand in New Brunswick; Rehab. of Pt. Lepreau, R. White (NB Power)

10:55 The Québec Scene; Rehab. of Gentilly-2, R. Pageau (H-Q)

11:20 Will there be a Future Uranium Supply Shortage, R. Pollock (Cogema)

12:00 Luncheon – Guest Speaker: Marvin Fertel, Senior VP and Chief Nuclear Officer, Nuclear Energy Institute; "Actions Underway to Facilitate the Plans for New Nuclear Plants in the USA"

14:00 to 16:50 Parallel Technical Sessions:
- Environment, Health & Medical
- Control Room & Operations I
- Safety Analysis & Licensing I
- Reactor Physics & Monitoring I
- New Fuel Design I

17:00 CNS Annual General Meeting (Open to all CNS members; Review of CNS Year + Election of CNS Council for 2004-05)

Tuesday June 8

08:30 to 11:50 Parallel Technical Sessions:
- Control Room & Operations II
- Safety Analysis & Licensing II
- Project Management
- Plant Life Improvement & Extension
- New Fuel Design II

09:00 Canadian Nuclear Association AGM

10:00 CNA Board meeting (Board members only)

12:00 Women in Nuclear (WIN) Workshop and Luncheon: Free - No Conference registration is required. Due to limited space, please pre-register with Cheryl Cottrill: 519-361-6582 or cheryl.cottrill@brucepower.com

Plenary II-A Future Challenges

13:35 Maintaining Nuclear Security – Status & Outlook, TBA (CNSC)

14:00 AECL Update re Anticipated New Projects and Expectations for Refurbishment, K. Petrunik (AECL)

14:25 Dominion's Early Site Permit Project in the USA, G. Grecheck (Dominion Energy Inc.)

14:50 Medical Applications: Positron Emission Tomography, K. Gulenchyn (Hamilton Health Sciences Centre)

15:15 Break

PlenaryII-B The Communication Challenges

15:45 Update from the NWMO, E. Dowdeswell

16:00 What's Happening at the CNA: Current Priorities, M. Elston (CNA)

16:25 The Port Hope LLRW Remediation Project, R. Austin (Mayor of Port Hope)

18:00 Reception: Cocktails and Music

18:45 Nuclear Achievement Awards Banquet (+ more music from the Climax Jazz Band)

Wednesday June 9

PlenaryIII-A Industry and Technical Challenges

08:30 Status of Cernavoda-2 and Challenges of Initiating Work on Unit 3, I. Rotaru (SNN S.A., Romania)

08:55 Canada's Role in the Generation IV Initiative, S. Bushby (NRCan)

09:20 The Challenges of Developing an SEU Program, R. Steane (Cameco)

09:45 Future Technical Challenges for CANDU, P. Fehrenbach (AECL)

10:10 Break

Plenary III-B: Meeting the People Challenges

10:40 The UNENE Initiative, and the World Nuclear University, M. Mathur (UNENE)

11:05 Establishing Nuclear Education at UOIT, T. Slobodian (UOIT)

11:30 Report on the International Youth Nuclear Congress, A. McLean (U. of Toronto)

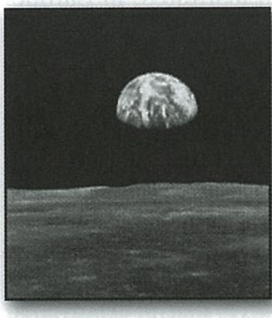
12:00 YGN Luncheon – Guest Speaker: Duncan Hawthorne, CEO of Bruce Power - "The Aging Industry; Planning for Succession; Bruce Power's Future Growth Prospects"

14:00 to 17:00 Parallel Technical Sessions:
- Control Room & Operations III
- Safety Analysis & Licensing III
- Plant Inspection & Maintenance
- Reactor Physics & Monitoring II
- Quality Management

Note: Accurate titles for papers will appear in the full program, which will be available by mid-May.

Making Nuclear Power Sustainable

by Bertrand Barré[1]



***Ed. Note:** The following article is reprinted from the December 2003 issue of the IAEA Bulletin.*

Even though it is almost 35 years old, there is a picture which still cannot be seen without emotion: the first photograph of the Earth shown as a modest white and blue dot in the black sky, beyond the barren desolation of the Moon in the foreground. This tiny planet, surrounded by the fragile bubble of its atmosphere, is our only home, and it will be eons, if ever, before humans can find another place to live. And our home is endangered. Let's state the facts:

1. Today over 6 billion human beings inhabit the earth, many of whom do not have enough available energy to enjoy a decent life. Tomorrow, there shall be 9 billion of us.
2. Within a mere century, we have pumped so much carbon dioxide and other greenhouse gases (GHGs) into the atmosphere that their concentration exceeds by far any level ever experienced by humans since their mastery of fire, half a million years ago.
3. All the available models predict that if we do not curb drastically our GHG emissions, we are bound for a catastrophe with dire consequences, a catastrophe which may be irreversible by human standards.

In summary, we must double our energy production while dividing by a factor of two our GHG emissions, knowing that today, 80% of our energy comes from the combustion of coal, gas and oil, all of which produce CO_2 released in the atmosphere. This is the toughest challenge facing us in the next few decades, and I include the water challenge, since producing drinking water will also increase our energy needs.

The future role of nuclear energy

This formidable challenge will not be easily met. No magic bullet is in sight, not even a nuclear bullet. To have any chance of success, we must actually implement all the available measures, and invent some more. In fact, we shall certainly need a three-pronged approach:

1. Increase energy efficiency to limit energy consumption in our developed countries;
2. Diversify our energy mix to reduce the share supplied by fossil fuels-and that translates into increasing nuclear and renewable energy sources;
3. Trap and sequester CO_2 wherever and whenever economically possible.

Without commenting further on the other measures, I will focus now on the nuclear issue. According to International Energy Agency (IEA) statistics, nuclear energy accounts today for 6.8% of the world energy supply[2]. Is it realistic to expect this share to grow, when many forecasts (including IEA's own) predict a slow reduction? The future is not engraved in marble, it is ours to make; the future role of nuclear power will depend on the results of our present efforts to expand or overcome its limitations.

Let's have a dream: It is quite possible that, within four decades, 40% of the electric power generated in all OECD (Organisation for Economic Cooperation and Development) countries, plus Russia, China, India and Brazil, comes from nuclear reactors. It is not far-fetched, when you consider that it took only two decades for France to increase its nuclear share of electricity from 8% to 80%. More ambitious, let's assume that in the same timeframe and within the same countries 15% of the fuels for transportation come from nuclear-produced hydrogen and that 10% of the space heating is supplied by nuclear heat. With more than 20% of the total energy generated by nuclear energy, even its most adamant adversaries could not pretend its role is marginal for sustainable development. The niche is there: will we be able to fill it?

The limits to nuclear growth

Economics need not be a problem: Internalising the costs of fossil fuels to even a small fraction of the environmental detriment of CO_2 will easily reinforce the competitiveness of nuclear power. One should nevertheless seek to reduce nuclear plant construction times and the level of initial investment.

Mineral resources, abundant under present growth assumptions, would limit a high nuclear growth scenario, unless we "rediscover" breeding fuel from uranium or thorium or both. It is not a mystery why four or five out of the six candidate concepts selected by the Generation IV International Forum are based on such recycling of fuel.

Today probably the strongest limitation to a high growth

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2 Having reached such a figure in 50 years is no trivial achievement: to generate the same amount of electricity that nuclear reactors do today, one would have to burn in modern oil-fired plants more than the total oil production of Saudi Arabia. But expectations were much higher a few decades ago.

scenario is public acceptance. The memory of Chernobyl is still vivid, and the delays in the decisions concerning the disposal of high-level radioactive wastes spread the idea that it is an intractable problem. It should however be pointed out that, since the Chernobyl accident, 8,000 reactor years have been accumulated without any reactor accident, and that much progress has been achieved in the waste disposal area-the operation of the Waste Isolation Power Plant (WIPP) in Carlsbad, USA and the overwhelming vote by the Finnish Parliament to build a repository, to name a few. Mitigation of the consequences of severe accidents is already a prominent feature of some "next generation" reactors.

Working together to overcome limitations

To make nuclear power sustainable, we have to overcome limits to its growth. In the past few years, several international initiatives were taken to that end. Let me evoke them in alphabetic order:

- **GIF: the Generation IV International Forum**

At the initiative of the US Department of Energy (USDOE), since 1999, ten countries have worked together to select a few model concepts for future nuclear systems, and to define and perform the research and development (R&D) necessary to make them ready for possible commercialization after 2030. Criteria for selection included sustainability (fissile resources utilization, waste minimization, proliferation resistance and physical protection), safety and reliability (radiation-protection, reactivity control, heat removal, mitigation features) and economics.

The six model concepts selected are:

1. Supercritical Water Cooled Reactor System;
2. Very High Temperature Reactor System;
3. Sodium Cooled Fast Reactor System;
4. Lead Alloy Cooled Fast Reactor System;
5. Gas Cooled Fast Reactor System;
6. Molten Salt Reactor System (this concept, the most futuristic, is not supported by some members).

- **INPRO: International Project on Innovative Nuclear Reactors & Fuel Cycles**

In 2000, the IAEA initiated the INPRO Project in which fifteen Member States have worked to define "User Requirements" for innovative nuclear energy systems in the area of economics, sustainability and environment, safety, waste management, proliferation resistance and some cross-cutting issues. They have also developed a methodology of assessment for such systems.

Based on similar analyses and motivations, the work of GIF and INPRO are not identical: GIF partners are mostly suppliers, and their work will steer the R&D, while INPRO expresses mostly the requirements of potential future users. Each group is quite aware of the other's results. Formulating future requirements and developing future concepts would be useless if, in the meantime, the main ingredient of excellence were lacking: trained and competent human resources. Such is the rationale behind the third initiative.

- **WNU: the World Nuclear University**

During the last decade, enrolment in nuclear engineering courses has been declining in many countries (although it appears that the trend is presently reversing in the USA). To counter this trend, several projects are creating regional networks of universities and institutes. In Europe, for instance, 25 academic institutions have founded the European Nuclear Education Network (ENEN), organized within the European Commission's 6th Framework Program, and a new "European Master's Degree" in nuclear engineering has been created recently. South Korea has been very active in proposing an Asian network, and several US universities have assembled such a network together with the main national laboratories of the DOE.

To expand this concept on an international scale, the IAEA, World Nuclear Association (WNA), World Association of Nuclear Operators (WANO) and the Nuclear Energy Agency (NEA) inaugurated last September the World Nuclear University (WNU). The WNU endeavours to promote academic rigor and high professional ethics in all phases of nuclear activity. Its agenda involves coordinating curricula, harmonizing degrees, promoting exchanges of students and teachers and facilitating distance learning.

Energy fuels development

Fifty years after the famous words of President Eisenhower to the UN General Assembly, the nuclear community is now working together to make nuclear power sustainable for the benefit of mankind. Let's hope that this cooperation will be fruitful because we know that without enough energy, there is no development. We know that nuclear power cannot be the answer, but we also know that there is probably no answer without nuclear power.

Safer Nuclear Energy for the Future

By Dan Meneley[1]

***Ed. Note:** The following paper is an updated version of the first of four lectures presented at the 28th International Summer College on Physics and Contemporary Needs, 30th June to 12 July 2003, in Nathiagali, Pakistan*

Introduction

The first question that arises under this heading is "Why?" Why do we need safer plants? Nuclear fission reactors have been used in power production for about 50 years. Over 400 power plants are operating in the world. A totally new energy supply has reached maturity thanks to the efforts of thousands of dedicated and brilliant people. Safety has been a paramount consideration since the beginning. Why do we now need even safer plants?

Two reasons are apparent. First, many people in the world are uncomfortable about the potential for disastrous accidents during operation. Though these fears may seem to be greatly exaggerated, their importance cannot be denied - they have had a profound negative influence on nuclear energy planning and installation over the past 40 years. They must be considered very seriously in the future.

Second, the future need for nuclear generating capacity is expected to be very large. As fossil fuel prices escalate the use of these fuels will become less and less affordable, so nuclear plants gradually will be substituted for them. Horizontal diversification into hydrogen production, transportation fuel production and many other energy-related products is likely. The world installed capacity some 50 years from today may be equivalent to at least 1000 units, each of 1000 MW output, or more than double today's installed capacity. The following 50 years might see a further 10-fold increase. In such a world, each of these nuclear plants must achieve an even higher level of public protection than exists today[2].

I. Safety Perspectives

The content of these four lectures reflects my own opinions, and in no way represents nor reflects the policies of Atomic Energy of Canada Limited. These opinions are the result of my interactions with this technology, and the people who have developed it, over the past forty years. The topic of safety is very broad. This limited space allows only a few words in an attempt to convey my own view of some important aspects of safety improvement. A slightly broader perspective can be found in the lecture notes of this series[3] on the CANTEACH website under the same title as this paper.

Common practice starts with the assumption that what we need to satisfy the people is a set of safer "technical fixes" that (we hope) will solve the problems of nuclear energy. A slightly different perspective is presented here. The technical examples given here relate mostly to the CANDU-PHWR system, simply because it is the system with which I am most familiar. Most of the lessons can be applied, however, to any nuclear plant concept.

I.1 Do You Feel Safe?

Given any situation (such as an aircraft in flight) an individual either feels safe or does not feel safe. This is hardly an objective concept. However, engineers work in the real world. This world is governed by people whose decisions are guided, not by the commonly used term "cold, hard, facts", but by their innate feeling about safety. When you tell a new acquaintance about your work, and you confess that you have spent half a lifetime working on nuclear power development, the most common first reply is "This is scary, isn't it?" After the next half hour of explanation that it really is <u>not</u> scary, most people are reassured - but not comforted. Most are still afraid. Such reassurance is convincing when everything is going well, but confidence quickly breaks down, and the fear takes over, when an accident occurs such as an aircraft crash or power plant accident. In my opinion, safety cannot be properly addressed solely in rational terms like reliability, defence in depth, and so on. To be successful, proponents also must address the underlying fear of nuclear energy.

The task of the safety engineer is to give most people a well-justified safe feeling about the nuclear energy supply system.

I.2 Objectives of Nuclear Safety

Three objectives are apparent: protection of the public, protection of the operating staff, and protection of the plant itself. Public protection is, naturally, the central issue considered during design and licensing proceedings. Protection of the plant is clearly in the interest of the owner. The owner's desire for investment protection lines up very well with the regulator's interest as well as the public interest. Protection of the operating staff also aligns very well with the need to control all releases of radioactive material.

The plant owners first must recognize that the plant they own is "fragile"[4] and can suffer severe and expensive damage even in cases where the public remains well pro-

1 Atomic Energy of Canada Limited (Engineer Emeritus)

tected. This is a fact, but not a fact that features in many of the sales brochures published by nuclear plant vendors. The people who own and operate the plant clearly have an interest in its safe operation. If the plant is damaged the first consequence falls on their staff and their financial investment. Economic assessments should, but most often do not, include the actuarial risk of losses (both production and material losses) during plant operation.

The safety regulator is in a position where he/she is charged as the auditor of the owner's safe performance. The regulator acts on behalf of the people - and so obviously has a central interest in safety. Issuance of an operating license is an explicit delegation of responsibility to operate the plant within the defined bounds. Commensurate authority also is delegated to the licensee. Responsibility, of course, also remains in full force with the regulatory agency. It cannot be reduced by delegation. Authority to operate confers on the operating organization the ultimate responsibility for safety[5].

I.3 The Human Side of Safety

A well-designed plant can be operated poorly and as a result might produce a major accident, while a poorly designed plant can be operated with care by competent operating staff, and as a result might be very safe. Lapses in care, knowledge, or attention are a consistent pattern in most major accidents, and it appears that the real standards of operational safety are determined largely by the philosophy of senior management

Close ties exist between the individuals running the plant and its achieved safe record of operation. These people are in the front line of safety. (Plants all have excellent radiation safety records until they begin to operate.). In all industries, post-facto review of accidents always reveals lapses by some humans - politicians, managers, designers, operating personnel, regulators, etc. It appears that a distinction can be made between safe and unsafe facilities, by examining the attitudes of senior management. These attitudes are infused throughout the organization and eventually result in failures. Poor management is the real root cause of most accidents. Regulatory oversight at the management level may be the most effective strategy to sustain safe operation.

I.4 Idealized Safety Management System

The diagram is intended only to represent primary working relationships and responsibilities. It is not an organization chart.

The base triangle shows the designer/builder at one apex and the regulatory staff at the other apex - and both supporting the operating organization that carries the primary responsibility for public safety. The authority for action by regulatory staff flows from the government-appointed Safety Standards Authority. The government establishes Safety Standards on behalf of the people. (International standards have no force within a country - but may be adopted by the government in some cases.) The scientific-technical commu-

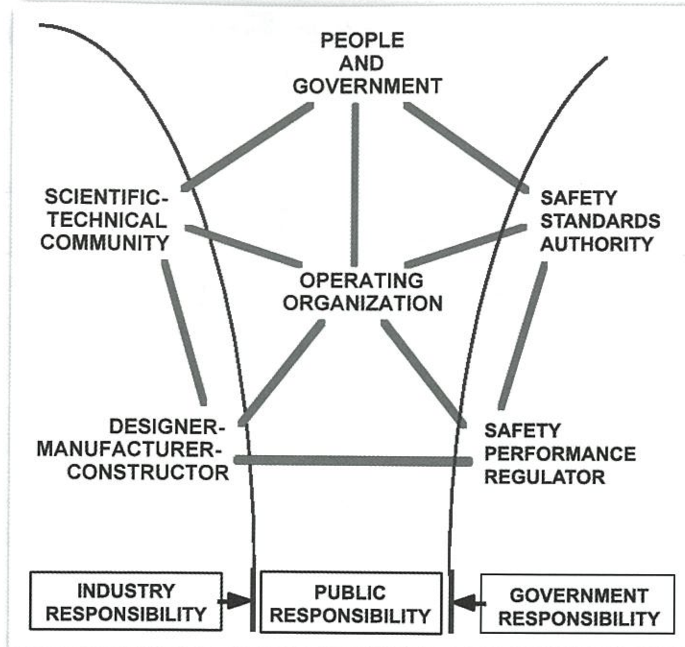

Figure I: Safety Management System

nity provides technical authority for safety. The government registers some members of this community under various education statutes. These statutes sometimes include the establishment of self-regulating engineering associations. Together, these two organizations carry technical responsibility for safe plant designs. Finally, the operating organization is supported and is delegated the authority to operate the plant within the bounds defined by technical and regulatory requirements. Engineering support for operations continues through the whole life of the plant.

I.5 Future Design Opportunities

Given today's advanced capability for automatic control and operation, the panel operator's cognitive ability will, in the future, be mostly reserved for analytical tasks and trouble-shooting. The panel operator's tasks will consist mostly in monitoring of automatic operation, monitoring of the state of plant systems, and initiating manual corrective actions as and when required. Extensive engineering support will be made available to the operating staff.

In addition to the well-developed nuclear safety design principles, the idea of "accident management" has been introduced to limit maximum consequences following any accident. In the future, plant designs can be chosen to further limit these consequences. The ultimate goal is to eliminate the possibility of serious health consequences outside the site boundary. This design direction is illustrated by the design concepts used in the most recent CANDU-PHWR plants, and well as those from other reactor vendors. Even today, German law requires designers to prove that no rapid evacuation of the population will ever be required following any accident in a new LWR plant in Germany.

I.6 Limits of Safety

The common assumption in nuclear plant safety analysis is that accident consequences are inversely proportional to their frequency of occurrence. Plant designs that rest on this assumption are vulnerable to criticism, in that they are capable of producing disastrously large consequences, albeit at some very low probability. Furthermore, recent evidence[6,7,8,9] indicates that unexpected events occur at an approximately constant rate in mature, tightly coupled, complex systems such as nuclear power plants.

James Reason[10] and others conclude that unexpected events are likely to be initiated at the human-machine interface. Given the possibility of large consequences following an accident, this finding easily could explain the unease that many people feel in the presence of a nuclear plant. Their rational selves might be reassured by the knowledge that the plant is in good hands and has been designed for a high level of safety, but this reassurance is unlikely to be strong enough to comfort their fears. Another approach should be considered.

I.7 The Next Steps

In the near future, the following general design approaches should be examined, aimed toward safer plant operation in the future. First, designers should utilize concepts that reduce the operators' workload. This step is a logical part of an approach that recognizes human performance as the main determinant of operational safety. Continuing a long-standing trend, designers are encouraged to use concepts that minimize the <u>likelihood</u> of plant damage. Further, features such as a large low-pressure heat sink inside containment can delay challenges to containment after shutdown. This principle follows the invocation "delay, delay, delay -- decay, decay, decay". Both heat production rates and residual radiation levels decay very rapidly following reactor shutdown. A delayed release from containment is very much less likely to be disastrous than is an early release.

In all instances, designers are encouraged to utilize design concepts that reduce the <u>maximum</u> consequences of any accident, regardless of its probability. This design perspective is intended to improve the "comfort" level of nuclear power plants.

II Past Design Evolution

During the past 50 years several (approximately 20) different power reactor concepts have been developed, at least up to the stage of a large prototype. Most of these prototypes have been decommissioned for one or the other set of reasons: technical, economic, performance, social, and so on. Three successful concepts can be considered to be "mature" at this time - PWR, BWR, and CANDU-PHWR. The majority of operating units in the world are of the PWR type.

II.1 Operating Experience

Many thousands of minor failures have, as expected, occurred in operating power plants over the past decades. Nearly all of these have been safely protected against by the several systems of defence built into these designs, without any damage to the fuel. (A good measure of successful termination of a failure event, in solid-fuel reactors of this type, is the absence of fuel failures. If this is achieved, release of large quantities of fission products to the environment is essentially impossible.)

Two major failure events resulting in fuel failures have occurred in recent years -- the Three Mile Island Unit 2 accident in 1979 and the Chernobyl Unit 4 accident in 1986.

Three Mile Island Unit 2 was a modern US pressurized water reactor, built to the standards of that day. Errors committed by designers, operators, and regulators led to a partial meltdown of the fuel that threatened the integrity of the pressure vessel. The result was zero environmental or health effects, but large financial losses. Many factors contributed to this complex event, but "unjustified self-confidence" can be seen as its root cause. The plant has not operated since.

Chernobyl Unit 4 was one of a nearly mature group of similar plants built by the USSR. These plants had a moderately long history of successful operation. Errors were committed by government, designers, regulators, managers, and operators that led directly to the death of about 40 people from combined effects of radiation and of an extraordinary fire that was one result of the event. In addition to health effects, the accident incurred a huge cost, equivalent to over 10 billion US dollars. Environmental consequences are still seen, nearly 20 years after the accident.

In addition to these major accidents, there have been several "near miss events" that are judged to be very near to causing fuel failures. One of the most dangerous of these near misses occurred at the Davis Besse PWR, another modern US-designed pressurized water reactor, in 2002. Slow corrosion of the pressure vessel steel led to a drastic weakening, under conditions of full reactor power. The root cause has not yet been finally determined, but a major factor was poor vigilance on the part of operating and management staff, over a period of years.

II.2 Institutional Failure

A different type of failure occurred at Ontario Hydro, an experienced utility in the Canadian nuclear industry, with a long record of successful operation. What is best described as an Operational Breakdown led in 1997 to shutdown of seven large units. Government, company directors, senior management, and others committed sundry errors. The plants were shut down safely, but major financial consequences have followed. Some years earlier, staff had been reduced drastically without proper consideration of resources needed for safe operation. Maintenance had been neglected at the several understaffed units. The units at Pickering A, and at least two at Bruce A now are being extensively refurbished in preparation for restart.

Mosey[11] examined Institutional Failure in the nuclear industry. Clearly, from consideration of the major events listed above, institutional failure played a part in each of them. From another perspective, the commonly used term "operator error" that appears in many accident reports must be expanded to include senior management and others, in most cases.

Management, because it (by definition) holds a great deal of authority over system operations, must accept some degree of responsibility for many of the failures in the systems. Front-line workers are no less fallible, but for them the consequences of poor performance usually is less damaging. An interesting book by Weick and Sutcliffe of the University of Michigan business school[12] takes up the theme and applies it to a wide analysis of failures in business. That book broadens our understanding of both the effects of the high-reliability approach and the reality of Normal Accidents, as presented earlier by Perrow.

III Today's Development Directions

Only a small number of reactor development efforts are underway in the world at the present time. These "paper" design projects are mainly aimed at significant cost reduction, because of the nearly exclusive desire of potential plant customers for new generation with low capital cost. As for construction of prototype plants, only one program (the PBMR in South Africa) is significant. Most active work among plant vendors is concentrated on refinement, or incremental evolutionary change, based on well established commercially proven designs.

With regard to safety, the dominant design direction at the present time is toward even greater reliance on high reliability systems. This would appear to be a good thing, both for public safety reasons and for protection of the plant investment. One country (Germany) has enacted legislation that explicitly requires new plant designs to limit the consequences of severe accidents to the surrounding population, regardless of accident probability. Germany is, however, very unlikely to undertake any new plant commitments in the foreseeable future.

Regardless of whether or not new reactor development projects are underway, the time taken between the "fully commercialized" state of any plant design and the later time when it can, even under optimistic assumptions, begin to have an important effect on the world energy supply is measured in decades. During the next fifty years, we must plan for a world in which predominant reactor types are nearly the same as those in service today[13]. If we foresee that a particular reactor type will be highly beneficial in about fifty years from today we must begin work on its introduction today, or at the latest within a few years.

Therefore it is very clear that the human performance component of nuclear plant safety is the preferred area for improvement, for two main reasons. First, the performance of all people supporting safe operation during this crucial period will determine whether or not we continue to suffer major accidents and "close calls". If we do continue in this way it is very unlikely that the public will continue to favour nuclear fission technology regardless of how vital it may be as an energy supply in the long term. The second reason to concentrate on the human dimension in safety is because improvements can be achieved in a comparatively short time. The best example is the remarkable improvement in US plant performance during the past two decades. The central motivation for this improvement was economics rather than safety; however, it is apparent from performance indicators that safety also has improved during this time.

Following is a brief summary of recommendations to designers in the immediate future, (a) reorganize the responsibility and authority structure of operating utilities and other members of the safety management system, (b) ensure that responsibility and commensurate authority are placed in the same hands, (c) recognize the realities of "normal" accidents, and (d) learn to manage the unexpected - it is expected to happen.

IV The Long Term

If a basic change in design direction is needed in the long term then that change must begin very soon, if it is to be effective within 50-100 years. The critical stages of such a change begin with at least one commitment to build a prototype plant featuring the new design. Someone must risk money and resources to make this happen. Within the present day risk-averse logic of world private-sector companies it is very unlikely that such a venture will be initiated. Government, or more likely a collaborative group of governments, is a more likely initiating mechanism for such a change. The weakness of such a venture lies in its distributed authority, wherein competing factions attempt to dominate the agenda, and the final plant design suffers as a result.

However, if we could ignore these difficulties and set off (theoretically) to choose a new nuclear plant concept, what would we wish to incorporate in its final characteristics?

First, the plant must be practical - it must exhibit competitive economics and must minimize the downside risk to its owner and to plant staff. The continuing assurance of low production cost in the long term, and of very low risk of plant damage should be factored into decisions on design alternatives, so that these risks are considered in the design process. One result of this approach will be higher assurance of good reliability and protection from plant damage. A second result will be a fuel cycle that assures a sustainable fuel supply forward about 100 years from the time the plant is built.

The second high priority choice would be for the plant to be run by a competent, dedicated and 'mindful'[12] operating staff. While it is relatively easy to assemble an excellent staff, it is much more difficult to sustain that excellence for several decades corresponding to the plant's useful life. Performance oversight and review must be a continuous process. Designs that simplify the operator's tasks, that use automatic systems to continuously monitor the condition of the plant systems and components, and designs that 'package' complex functions to the extent possible are more likely to support safe operation in the long-term future. Replaceable components and systems also will assist in achieving this goal.

Recognizing that failures will occur during operation, defence in depth will remain a key aspect of design. Designers also should recall the advice of Dr. John Foster[14], an early engineering manager at AECL: that a nuclear plant should be robust and sturdy -- more akin to a "Gravel Truck" than to a "Formula 1 Racer".

The ultimate defence against serious harm to the public is a plant design that cannot cause major consequences as a result of severe damage to its components and systems, at any frequency. Some designs approach this goal today, and some have inherent characteristics that make that target relatively easy to achieve. Combined with excellent defence in depth, this ultimate protection feature will permit nuclear energy to fulfill its promise of an abundant energy supply for humanity throughout the coming millennia.

V. Conclusion

Many opportunities exist for improving the safety of nuclear power plants, both in the everyday sense of reliable, steady plant operation and in terms of the greatest public safety concerns; that is, major accidents leading to offsite consequences. Introduction of significant improvement to the whole 'fleet' of the world's nuclear plants will take several decades. However, there is a real opportunity to improve the safety performance of the human safety management system in the short term. To begin, workers engaged in this great enterprise should first carefully consider what needs to be improved, and should then proceed confidently to build this new, excellent, and renewable energy source for the benefit of humanity.

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IYNC 2004

Over 300 young nuclear professionals from around the world combine business and fun at successful gathering in Toronto

Picture over 150 young (and not-so-young) people streaming down Yonge Street in downtown Toronto on a warm evening in May, led by **Adam McLean,** former chair of the Toronto Branch of the Canadian Nuclear Society, and you have some flavour of the spirit of the **2004 International Youth Nuclear Congress,** held in Toronto, May 9 - 14, 2004.

The parade from the Marriott Courtyard Hotel to a restaurant about 20 blocks away actually only involved about half of the almost 300 attendees from 35 countries at the meeting and marked the close of the first full day of the meeting.

IYNC 2004 was just the third such gathering organized by loosely linked groups under the banner of Young Generation in Nuclear. The first was in Bratislava, Slovakia in 2000, the second in Daejon, Korea in April 2002. This one was co-hosted by the North American Young Generation in Nuclear (NA-YGN) and the Canadian Nuclear Society and came about in Toronto primarily due to the lobbying and organizing skills of Adam McLean who was pursuing graduate studies at the University of Toronto when he began his crusade. A move to San Diego in early 2003, as a continuation of his studies, did not deter him or diminish his efforts. He became general co-chair of the meeting.

The Congress combined the features of a standard nuclear conference, such as invited plenary speakers and "technical" sessions on a wide range of topics, with reports on Young Generation in Nuclear activities around the world, a business meeting involving 40 representatives from 32 countries, and fun events including a run on Sunday afternoon and a "nuclear game show" Monday. The "game show" involved a nuclear trivia and activity contest between two teams, one of the young generation, called the "neutrons", and the other comprising "older" representatives who were called the "protons". It was close but the "neutrons" won despite many of the trivia questions being on nuclear history.

A further difference from typical nuclear meetings was the strong presence of young women. Close to 25 percent of the YGN delegates were of the "fairer sex. This added a small drama when the Finance Chair, Davinder Valeri, from AECL, rushed off to hospital on the Tuesday to give birth to a daughter.

Some of the sessions were on topics that tend to be avoided at most nuclear meetings, such as: "politics of nuclear" and "social status of the nuclear profession".

In parallel with the basic program the International Atomic Energy Agency ran a "special media training" workshop and IYNC held workshops on "effective communication" and "knowledge transfer". The Nuclear Waste Management Organization held a round-table discussion on the Wednesday afternoon.

An excellent buffet on the Sunday evening provided delegates an opportunity to meet and, in many cases, renew acquaintances made at the last IYNC in Korea two years ago.

The formal meeting began on the Monday morning with an opening plenary session involving short presentations by representatives of several national and international organizations and three country delegates. **Alexander Tisbulya,** from Russia, the chair of the IYNC Network, opened the meeting and then turned over the moderator role to **Shannon Bragg-Sitton,** of the USA, who was the technical chair of the conference.

Mark Gwozdecky, a Canadian who is director of Information at the International Atomic Energy Agency outlined the role of the IAEA and suggested to the young professionals in the room that they should consider working for the Agency.

John Ritch, director general of the World Nuclear Association, titled his talk A Global Crisis - A Crucial Profession". Showing some dramatic slides, several of which were from satellites, he commented that environmentalists have raised the awareness of climate change even if they have not embraced nuclear. He closed by mentioning the recent creation of the World Nuclear University through the combined efforts of the WNA with the IAEA, the Nuclear Energy Agency of the OECD, and the World Association of Nuclear Operators.

Murray Elston, president of the Canadian Nuclear Association, echoed the need for nuclear and suggested that new nuclear plants were likely to be built in Ontario. New models of financing will be needed, he added.

Angie Howard, of the Nuclear Energy Institute, began by noting that the US nuclear industry had met the challenge of deregulation of the electricity market. Performance is up, safety has been improved and costs are down, she stated, and several companies are pursuing pre-licensing approvals from the USNRC. The average age of staff in US nuclear utilities is about 50 years and many will be retiring within the next five years, she added, with the industry already seeing shortages of qualified people.

Then followed three country reports, from Argentina, Croatia and Korea.

Luippa Berlanga, of CNEA, Argentina, provided a concise overview of the extensive nuclear program in his country, which includes three nuclear power plants (one, Embalse, a CANDU 6), fuel manufacturing, research and isotope production. Work is proceeding on the development of a small, inherently safe, power rector, named CAREM.

Nikola Cavlina, representing the Nuclear Society of Croatia, offered the perspective of a small country. Croatia has a one-half share of the Krsko nuclear station, which is actually located across the border n Slovenia. Siting a plant in Croatia is difficult because no one wants any plant anywhere along the country's attractive Adriatic shoreline.

Chang Sun Kang, Seoul National University of Korea, spoke of the need for the public to balance between [perceived] nuclear-related and other societal risks. In particular he questioned the LNT (linear no threshold) dose-effect hypothesis and the misuse of "collective dose".

Following a break there were short reports from six national groups of the Young Generation Network. **Stewart Lynos** noted that the UK-YGN now had over 250 members. **Shoji Goto,** of Japan emphasized the question of employment, noting that knowledge and experience is being lost. He shocked some of his western counterparts by speaking of "short term" as 50 years and "long term" as 500 years when looking at history. **Amy Buu,** from Virginia, USA, speaking for the NA-YGN, gave an animated talk on how to organize a local group. "The more energized you are, the more energized you make others", was her key message. **Dennis Englerth,** also from the USA, provided a perspective of a YGN initiative within a large international company, AREVA. **Armando Gomez Torres,** Mexico, noted that the average age of nuclear workers in his country is now over 50 years. **Phuti Rueben Mogafe,** from South Africa, suffered computer problems, which were eventually solved after his talk so that he was able to show photos of many of the nuclear activities in his country.

Speaking at the Monday luncheon, **Larry Foulke,** president of the American Nuclear Society, urged attendees to "tell the story", commenting that anti-nuclear groups were not large but were good lobbyists. CNS president **Jeremy Whitlock** spoke at the closing session, Thursday afternoon.

Monday afternoon continued the plenary arrangement with a session on the "Advanced Reactor Debate" which began with a presentation by **Mel Caplan** of AECL on "ACR 700 - Building for the Future" who provided a brief history of CANDU and then outlined the features of the Advanced CANDU Reactor. The lack of illustrations hurt **Maurice Magugumada's** description of the pebble bed reactor being developed at his company, PBMR Ltd., South Africa. **Takeo Shimizu,** from Toshiba Company, Japan, spoke about their Advanced BWR plant, which, he stated, could be built in 34 months. **Regis Matzie,** from BNFL / Westinghouse described their AP 1000 design which six utilities had submitted for preliminary approval by the USNRC. In the question period all speakers noted that a limiting factor on construction time was now the time to build large components.

Beginning Tuesday morning the meeting split into two parallel sessions, on "Knowledge Transfer" and "Innovative Reactor Design". The former began with an invited paper by **Laurence Williams,** chief of the UK Nuclear Installations Inspectorate, while Regis Matzie led off in the other. Williams spoke of the "vital" need to maintain the knowledge base accumulated over a half century and to pass it on to future generations.

After the break there were three further parallel sessions: "Public Communication", "Power Plant Operations & Maintenance", and "Decommissioning, Waste Characterization & Immobilization". **Ken Ellis,** vice-president at Bruce Power, who gave the invited paper in the second session, commented "our ability to manage a technology rather than our ability to conceive and build it may be our limiting factor".

Over the following two days the pattern of parallel sessions continued with diverse topics such as: "Politics of nuclear"; "Natural systems and environmental impacts"; "Nuclear economics"; Medical applications"; "Industrial applications"; "Regulatory and institutional issues".

Special periods were allotted Tuesday and Wednesday afternoons to poster sessions, with a different set of posters for each period. This had the desired effect of bringing many delegates to examine the posters and discuss them with the authors.

For all of the sessions, including the poster ones, ballots were distributed and attendees urged to rate the presenters for awards to be presented the last day. (See list below.)

The official international meeting of the YGN was held on the Wednesday evening with 32 countries represented. Concluding that the loose arrangement needed to be replaced with a formal structure, the YGN leaders presented a set of By Laws, which, inevitably, led to an extended debate but eventual agreement. The vote on the location of the next IYNC was taken. Two proposals had been submitted, one from South Africa, the other from Sweden. After presentations by delegates from each country the group voted in favour of Sweden. So, IYNC 2006 will be held in Stockholm.

The meeting concluded with a dinner cruise, Thursday evening, on Lake Ontario. Following the Congress many delegates took in a trip to Niagara Falls on the Friday, which included a stop at the McMaster Nuclear Reactor.

IYNC 22004 was organized by a large "executive" committee of 24, with several sub-committees. As noted earlier, Adam McLean and Alexandre Tsibulya were the general co-chairs. Shannon Bragg-Sitton, LANL, USA, chaired the technical program committee.

Canadian members of the organizing teams were: Adam McLean, Kiza Francis (CNSC), Mark McIntyre (Atlantic Nuclear Services), Ruth Klatt (NSS), Thomas Wong (OPG), Davinder Valeri (AECL), Patrick Reid (Candesco Research), Yung Hoang (NSS), Eleodor Nichita (AECL), Peter Schwanke (AECL).

A large number of companies and organizations provided sponsorships. The "gold" sponsors were: AECL, AREVA, Bruce Power, CNS, Exelon Nuclear, IAEA, Korean Nuclear Society, Nuclear Energy Institute, Nuclear Society of Russia, Westinghouse.

Award winners

The organizers of IYNC 2004 gave out five awards for "best poster" and 23 awards for "oral" presentations. These were decided democratically by ballots distributed at each session. In addition a number of "fun" awards were made.

The winners were:

BEST POSTER PRESENTATIONS

Track: Social and Policy Issues
Session: Politics of Nuclear
Harry Deschwanden ("A Brief History About Radioactive Waste Disposal in Switzerland")

Track: Nuclear Fuel Cycle
Session: Safety and Reliability
J. Petzová and L'. Kupča ("Progress of Reactor Pressure Vessel Material Properties Evaluation by Small Punch Test Application")

Track: Non-Power Applications of Nuclear
Session: Industrial Applications
JiHee Nam ("Experience of Kaeri as an Internationally Authorized Laboratory for Test and Calibration"

Track: Nuclear Fuel Cycle
Session: Power Plant Operations and Maintenance
J. Cossaboom, S. Ranganathan and D.H. Lister ("The Fouling of Alloy-800 Heat Exchanger Tubes by Nickel Ferrite")

Track: Environmental and Waste Management
Session: Decommissioning, Waste Characterization, and Immobilization
Miroslav Băca and Vladimir Michal ("Using of a New Laser Scanning Technology for Decommissioning of NPP A-1")

BEST ORAL PRESENTATIONS

Session: Power Plant Operations and Maintenance I
Brent Williams ("Automated Validation Testing on the Bruce Power Training Simulators")

Session: Power Plan Operations and Maintenance II
Kristina Krištofová and Marek Vaško ("Decommissioning Activities for NPP A-1")

Session: Power Plant Operations and Maintenance III
Daniel Urjan ("Cernavoda Unit 1: Ensuring Adequate Heat Sink at Very Low Danube River Levels")

Session: Safety and Reliability I
Marian Kristof ("The Best Estimate Methodology in Licensing Applications")

Session: Safety and Reliability II
Peter Schwanke ("Effectiveness of the CANDU 6 Reactor Regulating System During a Liquid Zone-Control Pump Failure")

Session: Safety and Reliability III
Mark McIntyre ("The Definition of a Safe Operating Envelope")

Session: Young Generation Activities
Amy Buu and Brenda Brown ("NA-YGN Midlands - A Joint Local Chapter in South Carolina")

Session: Knowledge Transfer
Bum-Jin Chung ("Growing Concerns on Nuclear Manpower Shortage and Korean Initiatives")

Session: Innovative Reactor Designs
Christopher Cole ("Design of Small Nuclear Reactor for Extending the Operational Envelope of the Victoria Class Submarine")

Session: Public Communications
Alain Bucaille ("From Technical, Institutional and Societal Factors to Decision Making: A Contribution to the Global Analysis")

Session: Decommissioning, Waste Characterization, and Immobilization
Patrick Pin and Bertrand Perot ("Self-Induced X-Ray Fluorescence and Peak/Compton Comparison: Two Innovative Methods for Bituminized Waste Drum Characterization")

Session: Nuclear as a Part of the Energy Mix
Alistair I. Miller and Romney B. Duffey ("Pollution-Free Hydrogen From Nuclear Power")

Session: Space Applications and Radiation Dosimetry
S. De Grandis, E. Finzi, C.V. Lomardi, A. Maioli, and L. Summerer ("A PWR for a Mars Human Base")

Session: Politics of Nuclear
Philipp Hänggi ("Nuclear Energy in Switzerland: Yes Please!")

Session: Medical Applications
Vivian Pereyra Molina ("Holmium-166 Ferric Hidroxide Macroaggregates for Radiation Synovectomy")

Session: Nuclear Safeguards and Security
Branislav Hatala ("Safety Analysis for Fuel Licensing in the Slovak Republic")

Session: Natural Systems and Environmental Impacts
Ursula Alonso and Tiziana Missana ("Colloid Diffusion Studies at the Near / Far Field Interface of a HLWR")

Session: Nuclear Economics
Kai Salminen ("Civil Liability for Nuclear Damage - An Estimate of Long-Term Cost of a Possible Severe Reactor Accident in Finland")

Session: Accelerator Applications and Industrial Applications
Boris Sucic ("Nuclear Method for Humanitarian Demining")

Session: Thermohydraulics
A.A. Rovnov and S.M. Nikonov ("An Experimental Investigation of 11% LOCA's on PSB-VVER")

Session: Session: Engineered Systems
Laura-lee Brown, H.W. Bonin, and V.T. Bui ("The Combined Effects of Temperature, pH, and Radiation Exposure on the Degradation of Polymeric Materials Used in the Fabrication of Containers for the Disposal of Radioactive Waste"

Session: Nuclear Fuels and Fuel Recycling
B. Santos, J.J. NoÎl and D.W. Shoesmith ("Influence of Ca2+ on the Dissolution of Nuclear Fuel (UO2)")

Session: Regulatory and Institutional Issues
Corie Doyle ("The Canadian Risk Based Approach to Regulating Non-Power Applications of Nuclear Energy")

'FUN' AWARDS
Fluent in most languages: Taha Sutarwala - 5 (Canada)

Most years for degree: Shannon Bragg-Sitton (PhD 11) (USA)

Best spirit of international cooperation: Adam McLean (Canada)

Best ties or accessories: Patrick Reid (Canada)

Most congenial: Taha Sutarwala and Eugene Kogan (USA)

Ate the most: Ernst Thulin (Sweden)

Most severe weight loss: Davinder Valeri (Canada) (who gave birth to a daughter)

Youngest attendee: Maggie Fern (6 weeks) (USA)

Longest travel time: Magnus Winther (24 hours) (Sweden)

Scenes from IYNC 2004

A view of the IYNC International Meeting showing just one quarter of the delegates.

IYNC Network chair Alexander Tsibulya addresses the opening plenary of IYNC 2004 while technical chair Shannon Bragg-Sitton waits her turn.

Adam McLean shows off the official IYNC 2004 T-shirt

CAE wins contract for simulator for Swiss plant

In late April the Montreal based company, CAE, announced that it had been awarded a contract to develop a full-scale power-plant simulator for Switzerland's Beznau nuclear power plant, owned and operated by Nordostschweizerische Kraftwerke AG (NOK).

The order, valued at approximately $13 million, is the biggest win for CAE's power systems and simulation group in fiscal year 2004. Completion of the simulator is slated for the end of 2006.

The simulator will service two Westinghouse pressurized water reactor units at the Beznau site in northeastern Switzerland. The identical Beznau 1 and 2 units, each with a rated net output of 365 MWe, have been supplying reliable, safe and clean energy to nine cantons since 1969 and 1971, respectively.

The majority of the simulator's models will be developed, validated and maintained in CAE's ROSE® simulation environment. The simulator will be equipped with full replica control room panels and a user-friendly instructor station. Various plant computer systems will also be included in the simulator's scope of supply.

A week earlier CAE reported on five simulator upgrade contracts worth more than $3 million for nuclear power plants in the USA owned by AmerenUE, Florida Power & Light Company, Duke Energy and Exelon, and from Westinghouse Electric Company.

For AmerenUE, CAE will upgrade the Callaway Plant simulator's steam generator models with CAE's ROSE® and re-platform its simulation computer and instructor station with PCs that run CAE's latest operating environment.

Florida Power & Light Co. has ordered a similar re-platform of its simulation computer and instructor station originally delivered by CAE in 1987 for the St. Lucie (PWR) nuclear power plant on Hutchinson Island in Florida.

At Duke Energy's McGuire nuclear station, CAE will upgrade the simulator's electrical systems models, including its electrical grid, switchyard, AC electrical distribution system, main generator auxiliaries and emergency diesel generators.

For Exelon CAE will develop reactor core and thermal-hydraulic models for the Three Mile Island 1 simulator.

McMaster Nuclear Reactor celebrates 45th anniversary

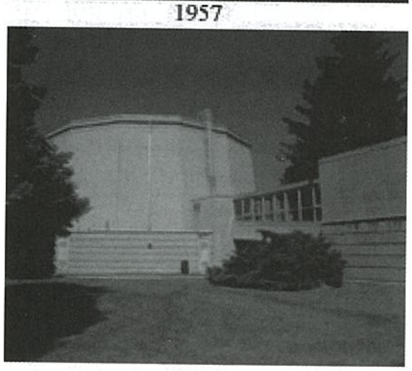
On April 4, 2004 McMaster University's Nuclear Reactor (MNR) marked its 45th anniversary. The reactor, built under the leadership of former McMaster President Harry Thode, was opened in 1959 by John Diefenbaker, then Prime Minister of Canada. It was the first university-based research reactor in the British Commonwealth and today is the only Canadian medium flux

The pool-type research reactor operates weekdays from 8 a.m. to 12 p.m. at a thermal power of two megawatts. It supports isotope production and research in a variety of areas such as neutron beam experiments, neutron activation and neutron radiography. It is also an educational tool for students in engineering, science and health and radiation physics. Nobel Prize winner Bertram Brockhouse was one of MNR's early researchers.

A number of small Canadian companies use the neutrons produced in MNR for a variety of applications, including examination of aircraft components and analysis of mine samples.

Last year the university created the McMaster Institute of Applied Radiation Sciences with the MNR as a key element.

1957



2004

Then and now: A view of the beginning of construction of the nuclear reactor in 1957 and a recent photo of the facility. Photo courtesy McMaster Nuclear Reactor

OPG issues comprehensive report

Under the prosaic title *"Annual Information Form"* Ontario Power Generation placed on its website the end of April 2004 an 85 page report that provides a concise but comprehensive review of all of its operations. Although aimed at the investment community the report offers background on the restructuring of Ontario Hydro, evolution of the electricity market, the Pickering A Review Panel and the OPG Review Committee whose report was issued in March 2004. The section on nuclear operations shows that the 2003 capacity factor for Darlington was 80.4% and that for Pickering B was 69.3%. Information on the extensive regulatory environment in which OPG operates is provided.

In March OPG issued a concise (10 pages) document entitled *"Backgrounder on the Nuclear Recovery Program"* It summarizes results as "Darlington - surpassed production target - costs significantly higher than forecast"; "Pickering B - production slightly below target - costs significantly higher than forecast". The cost estimates were flawed because (1) modeling projections, specifically comparison between PWR and CANDU, were not reliable, and (2) initial scoping was inadequate and delays in allocating staff.

Bruce 6 power increased slightly

Bruce Power has raised the power of its Unit 6 reactor by 26 MWe following approval by the Canadian Nuclear Safety Commission to increase the licensed power of the Bruce B units from 90% to 93% of design power.

When Bruce Power assumed operational control of the site, the Bruce B units were operating at 90 per cent reactor power in order to ensure safety margins met the requirements of the CNSC. Over the past two years, extensive analysis has shown that fuel-loading modifications and a decrease in the number of bundles from 13 to 12 in each fuel channel enhances reactor safety margins. Following a thorough review and implementation of these changes, the CNSC has approved the power increase. Raising reactor power to 93 per cent on Unit 6 is part of Bruce Power's long-term Improved Output Program to enhance safety and reliability of all four Bruce B units.

Other initiatives, which include turbine generator upgrades, a new fuel design and improvements to the reactor core, are expected to result in increase generation of up to 400 MWe over the next four years from Bruce B.

CNSC reaches out

The Canadian Nuclear Safety Commission is going to northern Saskatchewan to meet and hear from the people most affected by Canada's uranium mining industry, the native population of that area.

The CNSC will first hold a one-day hearing in Saskatoon on June 8 to consider an application from the Canadian Light Source cyclotron facility at the University of Saskatchewan to begin "routine operation".

Then the Commission will travel some 300 km north to La Ronge, the largest community in northern Saskatchewan, but still hundreds of kilometres south of the Saskatchewan basin location of the mines. The two licensing topics on the agenda are: the second day hearing on the application from Comeco to decommission the Cluff Lake mine; and a one day hearing on the environmental assessment screening report for the proposed Cigar Lake mine. Cigar Lake is owned 50% by Comeco, 37% by Cogema and the balance by two Japanese companies. It is estimated to have 90 million tonnes of uranium at an average grade of 19%.

In other CNSC news, on April 28, the Commission held the first of a two-day hearing on the application from Ontario Power Generation for a Construction Licence for a dry storage facility at Darlington. If approved after the second day hearing on July 9 the first phase of the facility is scheduled to be completed by 2007. Currently spent fuel at Darlington is stored in the two water bays.

Cameco To Develop Uranium Mine In Kazakhstan

Cameco Corporation and the National Atomic Company of Kazakhstan (KazAtomProm) plan to develop the Inkai uranium deposit in Kazakhstan through an Inkai Joint Venture (JV Inkai).

Cameco owns 60% of Inkai and KazAtomProm owns 40%. JV Inkai has approved the technical and financial conclusions of the feasibility study that estimated a total capital cost of $38 million (US) to build an in situ leach mine. Subject to regulatory approval, the mine is expected to achieve commercial production in 2007 and ramp up to 2.6 million pounds annually by 2009.

Cameco estimates there are 91.5 million pounds of proven and probable reserves that would provide an estimated mine life of well over 30 years. Additional work is required to confirm other resources that have been identified in the surrounding area.

Cameco expects construction to begin early in 2005, with completion scheduled for 2007. Inkai will employ up to 200 workers during construction and will require approximately 230 employees once full production is reached. Approximately 97% of the employees will be hired locally.

The Inkai deposit is located in south central Kazakhstan, about 370 kilometres northwest of the regional capital of Shymkent and some 1,000 kilometres northwest of Almaty. Small-scale test mining was conducted in the vicinity of Inkai in the late 1980s. JV Inkai began testing mining in 2002 in order to gather information for the feasibility study. In 2003 the test mine produced 0.2 million pounds U_3O_8 and is expected to continue to produce about 0.3 to 0.6 million pounds annually through 2007.

Point Lepreau in planned maintenance outage

The Point Lepreau Generating Station began a planned maintenance outage late Friday, April 30, 2004 which will continue through the remainder of May into early June.

During the outage station staff and contractors will perform the following maintenance and inspection activities:

- reactor building leak rate test
- feeder pipes inspections
- fuel channels inspections
- steam generators inspections
- turbine inspections
- heat transport pump seal replacement
- motorized valve inspections
- other maintenance and inspections which can only occur when the plant is in shutdown state

The station's capacity factor was 85.6 percent for the past fiscal year, the best capacity factor since 1994/95. There were no unplanned shutdowns at the station since the last planned maintenance outage.

In March 2004 the station exceeded one million person-hours without a lost time accident. This is the third time this milestone has been reached in the past four years.

Appointments

Gail Marcus, former president of the American Nuclear Society and recently General Chair of the 14th Pacific Basin Nuclear Conference has been appointed Deputy Director-General of the Nuclear Energy Agency (NEA), succeeding Ms. Carol Kessler. Dr. Marcus took up her duties at the NEA on 5 April 2004.

Dr. Marcus, who is of American nationality, holds the following degrees: a Doctor of Science in Nuclear Engineering and both a Bachelor and Master of Science in Physics from the Massachusetts Institute of Technology.

From 1999 to March 2004, Dr. Marcus was the Principal Deputy Director of the Office of Nuclear Energy, Science and Technology at the US Department of Energy. She carried out the research programme on advanced reactor designs, and managed the DOE research reactors, isotope production programmes, space reactor programmes and other nuclear energy initiatives.

In 1998-1999, as Visiting Professor at the Tokyo Institute of Technology, she conducted research on nuclear regulatory policy and, from 1985 to 1999, she held several senior positions at the US Nuclear Regulatory Commission in Washington, DC. From 1980 to 1985, she was Assistant Chief of the Science Policy Division of the Congressional Research Service in Washington, DC.

Patrick Lamarre was appointed President and Chief Executive Officer of Canatom NPM March 22, 2004 replacing Wayne Boyd who has moved to SNC-Lavalin. Canatom NPM was a major partner in the Qinshan project in China.

Patrick has experience in the areas of project management, financing and construction, where he has been given ever-increasing responsibilities. He is currently working on the $1.4 billion Alouette Phase II Expansion project as Deputy Project Manager. His previous positions included Marketing and Operation Manager of the Venezuela office, President of Hugo, an information technology outsourcing firm in Venezuela, Project Director of large M&M and industrial projects and Project Manager of BOOT studies. He is a graduate of the University of Waterloo, where he obtained his B.Sc. in Chemical Engineering.

He is located at Canatom NPM's Mississauga, Ontario, office where he will be managing the activities of Canatom NPM.

Joe Fontana, Parliamentary Secretary to the Prime Minister with special emphasis on Science and Small Business, and Member of Parliament for London North Centre, has been appointed Chair of the Council of Science and Technology Advisors (CSTA).The Council of Science and Technology Advisors is an independent, expert advisory body that provides advice to the federal Cabinet on the strategic management of the government's internal science and technology enterprise. The CSTA was created in 1998 in response to the 1996 federal science and technology strategy, which called for greater government reliance onexternal advice. CSTA membership is drawn from the academic, private and not-for-profit sectors, and reflects the diversity of science and technology-based disciplines. Through its advice, the Council seeks to improve the management of federal science and technology by examining issues that cut across science-based departments and agencies, and by highlighting opportunities for synergy and joint action.

US utility chooses ACR

Dominion Energy Incorporated, a utility company based in Virginia, has applied to the US Department of Energy for financial support for an application to the US Nuclear Regulatory Commission for a combined construction and operating licence for two ACR 700 units to be built on its North Anna site in Virginia. Under the program the Department of Energy would cover up to half the projected $500 million cost of the process.

As well as Dominion, Atomic Energy of Canada Limited will have Hitachi America Ltd. and Bechtel Power Corporation as partners. It is projected that the review could take up to six years. A major task will be in certifying the ACR design to USNRC rules.

Obituaries

Delmar Tegart

An early pioneer at the Chalk River Laboratories, Delmar Robinson (Del) Tegart, passed away peacefully in Calgary on March 16, 2004.

Del was born in Lumsden, Saskatchewan on July 29, 1912. He graduated from the University of Alberta in 1936. Following the Second World War he joined the Chalk River Project of the National Research Council, which became part of Atomic Energy of Canada Limited when that company was formed in 1952. He was involved in the commissioning and operation of the NRX reactor and subsequently of the similar CIR (now called CIRUS) reactor in India. Later he moved to the Whiteshell Laboratories in Manitoba. Before retiring he was part of the Wolsong 1 team in Seoul, Korea.

Del is survived by his wife of 60 years, Elizabeth (Betty), his son, Lyall and treasured friend (Lyall's partner) Evelyn.

A celebration of Del's life will take place June 20, 2004. To send condolences, email – tegart@shaw.ca

Keith Harvey

Keith Bryan Harvey died April 29, 2004 in Pinawa after a six-month struggle with cancer.

Born in Smethwick, in the United Kingdom, Keith grew up in Kidderminster, Worcestershire. He began his career in science at Steatite and Porcelain Products Ltd. in Stourport-on-Severn. He continued his education part-time and earned a double First Class Honours degree in Physics, Pure and Applied Mathematics from the University of London. He later earned his Ph.D. in Solid State Physics from the University of Bristol. After a year's sabbatical at the National Bureau of Standards in Washington, DC, he returned to Steatite. In 1972 he emigrated with his family to Québec City where he worked for the Centre de la Recherche Industrielle du Québec for three years, followed by three years in Fredericton, New Brunswick, working for the provincial Research and Productivity Council.

In 1979 he moved to Pinawa, Manitoba, to work at Atomic Energy of Canada Limited in the Nuclear Fuel Waste Management Program, working primarily on the development of glass compounds for immobilization of nuclear waste, and researching the dissolution of waste products and their migration through granite. After retiring from AECL in 1998, he gave many hours of volunteer service to the Economic Development Agency of Whiteshell. He was founding director of the Whiteshell Branch of the Deep River Science Academy, served as a School Trustee, secretary to the local Federal Superannuates National Association, and director and treasurer for JUST Corporation Inc. He was a member of the Canadian Nuclear Society since 1993.

He became involved with the Deep River Science Academy out of his passion for science and desire to ensure that young people would always have an opportunity to learn and grow. Keith loved living in Pinawa and was committed to maintaining the town's natural beauty and wildlife.

He is mourned by his wife, Kay, daughter Cheryl (Craig), sons Neil, Mark, Kevin (Ros) and Robert. His quiet kindness and dry humour will be deeply missed by both his family and many friends.

Francis Malcolm Fraser

Frank Fraser, a pioneer in Canada's radioisotope field and a champion of cobalt 60 based technologies, died in Ottawa May 17, 2004 at the age of 68.

Born in Montreal October 26, 1935, Frank was an athlete who played hockey, baseball and professional football with several teams in the Canadian Football League including the Ottawa Roughriders. After obtaining a B.Sc. from Tennessee State University he joined the Commercial Products of Atomic Energy of Canada Limited in 1958 on a part-time basis while still playing professional football. He became a full-time employee in 1964 and thereafter rose through the management ranks becoming Vice-President, Industrial Irradiation Division in the early 1990s. He was Vice-President, Market Development of MDS Nordion, the successor company to AECL Commercial Products, when he retired in 1998.

He oversaw the design, supply and installation of most of the industrial irradiation plants now operating in over 40 countries. He also played a major role in the establishment of the Canadian Irradiation Centre in Laval, Quebec and was Deputy Chairman of the UN International Consultative Group on Food Irradiation.

Frank was very active in the community and led MDS Nordion to be a major supporter of the Western Ottawa Community Resource Centre through an annual golf tournament and other activities.

Cremation took place shortly after his death. A gathering to celebrate his life was scheduled for May 26 at the National Arts Centre in Ottawa.

CNS news

CNS bids for PBNC 2008

CNS secretary, Ben Rouben, supported by president Jeremy Whitlock and Bulletin editor Fred Boyd, made an initial presentation at the meeting of the Pacific Nuclear Council in Hawaii, March 21, 2004, to hold the 2008 Pacific Basin Nuclear Conference in Vancouver in either August or September. That would be the tenth anniversary of the very successful 1998 PBNC which Canada held in Banff, Alberta.

Two other countries are vying for the right to hold PBNC 2008, Japan and Mexico. Japan proposes to hold the meeting in Aomori on its north island near its large fuel cycle facility at Rokkasho. Mexico proposes to hold the conference in Los Cabos, a resort area at the southern tip of Baja California, in September

The final decision will be made at the next PNC meeting scheduled to be held in conjunction with the American Nuclear Society winter meeting in Washington, November 14, 2004.

The CNS has the preliminary support of Atomic Energy of Canada Limited and other organizations of the Canadian nuclear community.

Pioneers to be honoured

In recognition of the 25th anniversary of the Society, CNS Council has decided to honour a few members who were very involved in its creation and early operation. They will be named "honorary life members" at a special function during the 25th Annual Conference in Toronto in June 2004. A full report will be included in the next issue of the CNS Bulletin.

President very active

CNS president Jeremy Whitlock has been "on the road" a great deal over the past couple of months representing the Society. This has included:

- delegate to the 14th Pacific Basin Nuclear Conference in March in Honolulu (which included participation in the presentation of the CNS' bid for PBNC 2008 in Vancouver)
- a visit to the New Brunswick CNS Branch on April 6, which included giving a noon talk at the Point Lepreau GS and an evening talk at University of Fredericton. In addition he had an unexpected interview (mostly on the subject of PLGS refurbishment) on the CBC Radio One morning show out of St. John, which aired for about five minutes' duration during the morning commute (about 8 AM) on Wednesday, April 7. The local arrangements were made by New Brunswick Branch chair Mark McIntyre and Willy Cook
- a meeting with representatives of the Ontario Science Centre meeting on April 29.
- participation in a Teachers' Workshop at McMaster University, April 30 (demonstrating a cloud chamber workshop and presenting some closing remarks)
- attendance at the 2004 International Youth Nuclear Congress in Toronto, May 9-13 where he presented the technical session awards and gave closing plenary remarks

In addition to his CNS activities Jeremy has been elected to the Board of the American Nuclear Society for a three-year term beginning in June 2004.

Paul Fehrenbach becomes PNC president

Paul Fehrenbach (L) receives the symbolic gavel of office as incoming President of the Pacific Nuclear Council from Mamoru Akiyama at a special ceremony held during the 14th Pacific Basin Nuclear Conference in Hawaii, March 2004

Paul Fehrenbach, vice-president, nuclear laboratories at Atomic Energy of Canada Limited, was installed as president of the Pacific Nuclear Council at a special ceremony during the recent 14th Pacific Basin Nuclear Conference in Hawaii in March 2004. The membership of the PNC includes nuclear societies, associations and other organizations from countries around the Pacific Rim. It conducts studies and workshops to enhance nuclear cooperation among its members. Paul's term of office is for two years.

BRANCH ACTIVITIES

Bruce *Eric Williams*

Ron Mottram, VP Bruce A Restart, addressed the Branch on Wednesday, May 2, on *The Bruce A Units 3 and 4 Restart Project, the Lessons Learned.*

Brent Williams, Simulator Services, is scheduled to share his experience on the *2004 International Youth Nuclear Congress* on Wednesday, June 23.

Dr. Jerry Cuttler, Cuttler and Associates, has agreed to talk on Wednesday, July 21, on *What To Do With Used CANDU Fuel? Is It Really Waste?*

The Bruce Branch website is up and running thanks to the efforts of Ms. Michelle Lapointe with the cooperation of Morgan Brown who made the CNS Website accessible from the Bruce Power Site.

Chalk River *Morgan Brown*

Eric Davey (Crew Systems Solutions) gave a presentation on *"Human factors in reactor control rooms"* on April 1. It was a very successful talk with a very good turnout.

Mark Porringa is scheduled to speak on *"Low Energy Induced Nuclear Fusion Via Coherence Of The Quantum Vacuum, Zero-Point Energy Through Ultra Close Range Casimir Effects"*, in May.

3) The *"Beneficial Applications Of Nuclear Science & Technology"* essay contest http://www.cns-snc.ca/branches/ChalkRiver/essaycontest..pdf is proceeding well. Blair Bromley, who is leading it, received 4 essays. Blair, Morgan Brown and Michael Stephens ranked the essays. They are proposing to invite the winners to supper and to present them with their prizes at a CNS meeting.

New Brunswick *Mark McIntyre*

The CNS New Brunswick provided two $50 prizes at the 32nd Annual New Brunswick Science Fair Finals and representatives do the judging. Premier Bernard Lord was expected to be at the awards ceremony.

Ottawa *Bob Dixon*

The CNS Ottawa branch held it's last seminar of the 2003-2004 session on Thursday, April 22 with Mike Taylor, former director of regulatory affairs at the Canadian Nuclear Safety Commission recalling some of his experiences as a nuclear submarine commander in the UK Navy under the title *"Nuclear on the Move: By Submarine to the North Pole"*.

The Branch contributed to the Ottawa Regional Science Fair and offered a $75 prize for a project related to nuclear science or technology. Fred Boyd and Bob Dixon attended the Science Fair on April10 but, unfortunately, none of the exhibits met the criteria for the prize.

Pickering *Marc Paiment*

CNS President, Jeremy Whitlock, gave a talk on the MAPLE isotope producing reactors at a seminar March 11 and included a "sales pitch" for membership in the Society. About 100 copies of the March 2004 issue of the *CNS Bulletin* were distributed.

Sheridan Park *Adriann Buijs*

Ronald Bartholomew, a former executive with Ontario Hydro, was scheduled to speak, May 19, on *A Perspective on the Status and Future of Nuclear Power in Ontario,* covering why Ontario Hydro began its nuclear program, what went wrong over the past two decades, and his view of the future.

Toronto *Bob Hemmings*

The January talk by Grant Malkoske, vice-president, MDS Nordion, was well received by approximately 40 attendees at the OPG facility. The February program had to be cancelled because of sudden unavailability of the speaker and there was no March program because of Spring Break.

The April program on "Natural Background Radiation" was substituted by *"What to do with used CANDU fuel? Is it really waste?"* by Jerry Cutler. It was well received by about 60 attendees at the U of T Chemical Engineering Presentation room.

The May program is set: Paul Gierszewski will speak at the OPG auditorium on *"Deep Geological Repositories"*.

The Branch will hold an AGM in June.

The Toronto Branch and the Sheridan Park Branch are sharing ideas for presentation ideas and speakers. The April meeting in Toronto featured the same program as did the Sheridan Park meeting a month previous. We look forward to more of this cooperation between Branches.

The Toronto Branch also took part in the April 2004 Toronto Sci-Tech Fair by issuing a cheque of $500 to the organization, continuing our tradition of this type of support. The contribution was for two prizes of $100 each, for outstanding projects that explore a topic in the nuclear field, and $300 for general running costs of the fair. The CNS Toronto Branch was there for the presentation of prizes along with suitable certificates, as we had done in the past.

Officers' Seminar

Eric Williams, chair of Branch Affairs reports that the proposed date for the 2004 CNS Officers Seminar is August 27 to be held in the Toronto / Sheridan Park area. Preliminary plans include a social dinner the night before, review of CNS Council Committees and Chairs, brief review of Branch Operations (how do we do what we do?), and a workshop on a topic to be determined (how to administer local branches, ideas for outreach projects, etc.).

Luxat moves to McMaster

John Luxat, long-time safety expert at Ontario Hydro and more recently Nuclear Safety Solutions, has moved to McMaster University where he has been appointed Professor and NSERC/UNENE Industrial Research Chair in Nuclear Safety Analysis. He took up the new post at the beginning of May 2004. His new e-mail address is <luxatj@mcmaster.ca>

Members of the CNS 2003 - 2004 Council are seen during a break at the January 30, 2004 Council meeting. L to R: John Luxat, Bill schneider, Dave Jackson, Dorin Nichita, Bryan White, Roman Sejnoha, Ken Smith, Jim Harvie, Ben Rouben, Denise Rouben, Jeremy Whitlock, Murray Stewart, Ed Hinchley, Michel Rhéaume, Adriaan Buijs, Bob Hemmings, Ian wilson, Ed Price, Parviz Gulshani, Andrew Lee, Jerry Cuttler.

Shown are five of the members of the 2003 - 2004 CNS executive, during the January 30, 2004 Council meeting. L to R Ben Rouben (secretary); Bill Schneider (1st V.P.); Jeremy whitlock (president); Ed Hinchley (treasurer); Ian Wilson (past-president) Absent: Walter Thompson (2nd V.P.)

BOOK REVIEW

Fuelling the Future

ed. Andrew Heintzman & Evan Solomon
House of Anansi Press, 2003, 396 p.
ISBN 0-88784-695-5

This is a collection of essays on the broad topic of energy . Its sub-title is *How the battle over energy is changing everything.* Authors include Thomas Homer-Dixon, author of The Ingenuity Gap and head of the recently renamed Pierre Elliott Trudeau Centre at the University of Toronto. Geoffrey Ballard has a chapter on "hydricity" and Jerry Rifkin writes on the companion topic "hydrogen economy". Ottawa environmentalist David Brooks provides a chapter on "Soft energy paths". The chapter on nuclear is written by Allison MacFarlane, an associate professor of international affairs and atmospheric science at Georgia Tech., and is quite negative in tone because of waste and proliferation problems.

Publications available

Radiation, People and the Environment

International Atomic Energy Agency, 2004, 80 p.
(Available free from the IAEA)

The sub-title gives a sense of this interesting and informative booklet. It reads *A broad overview of ionizing radiation, its effects and uses, as well as the measures in place to use it safely.* With the help of colour illustrations the booklet covers the basics of radiation (natural and man-made), sources, effects, system of radiological protection, nuclear power, waste managment and transport.. It could be a useful resource for talks to the general public.

Backgrounder on the Nuclear Recovery Program

Ontario Power Generation Inc. 2004

This concise 10 page report was placed on the OPG website in March 2004. Some of its conclusions are: "the results of the nuclear recovery plan have been mixed ....safety margins have been increased ...Pickering A was siginificantly delayed and above budget....while NAOP included some limited funding to deal with discovery work it proves to be inadequate.

Final report on the August 14, 2003 blackout in the United States and Canada

This is the sequel and conclusion of the interim report on the blackout that was issued in December 2003. It is available through the websites of the Canadian Nuclear Safety Commission
<<www.nuclearsafety.gc.ca> and Natural Resources Canada < www.nrcan.gc.ca>

Nuclear electricity generation: What are the external costs ?

Nuclear Energy Agency of the Organisation for Economic Cooperation and Development 2003

This 68 page report examines the internalised and external cost of nuclear generated electricity and how more of the external costs can be internalised.

It is available from the NEA website: <www.nea.fr>

Government and Nuclear Energy

Nuclear Energy Agency of the OECD, 2004
ISBN 92-64-01538-8, 91 p., $26 US

Bob Morrison, formerly at Natural Resources Canada, was the principal author of this report.

The report makes the case that despite the increase in the roles of markets, competition and privatization in the electricity and nuclear sector, and in some cases because of it, governments still have important roles to play, most notably in the establishing of overall energy policies, including the fair and effective functioning of markets. It also underlines the continuing importance of the government role in regulation and safety, and in longer-term activities such as R&D and waste management.

All's Well That Ends Well

by Jeremy Whitlock

We need to disposition our nuclear waste.

You mean "dispose"?

No, "disposition". We don't dispose any more.

But disposition isn't a verb.

Yes it is. Everyone uses it.

You mean the ones who use "nuclear" as a noun, and "chair" instead of "chairman"?

Yes them.

Okay, so what "disposition" are we talking about?

Safe. Secure. Monitored. Retrievable.

Retrievable? It's not really "nuclear waste" then is it? It's "slightly-used nuclear fuel".

Not that kind of retrievable. Don't even start talking about reprocessing. Just...retrievable. In case something goes wrong.

Go wrong? What can go wrong? And in any case isn't it less of a risk to dispose of it?

Now stop talking about risk. That's got nothing to do with public policy.

Sorry. So, it's retrievable because we might want to retrieve it, but not because it might be useful, and especially if we don't dispose of it.

Something like that.

But isn't this what we already do?

Of course it is. But we did it without consulting the public. If it doesn't have broad public support, it's not safe. So now we're consulting the public.

But the experts say it's safe right?

Yes, but technical safety is only half of it: if it's not "socially safe", it's only 50% safe. That's what Energy Probe says.

Oh I see. Then it must be right.

Look, it's attitudes like yours that got us where we are today: thinking that experts know what they're talking about.

That's not fair. I don't tell my doctor what to do.

But people trust doctors.

But doctors have killed more people than nuclear power ever will.

Now you're getting silly again.

So how do we demonstrate "broad public support"? A referendum?

Too impractical. We have to talk to small groups. Engage people. Show them the options. Ask their opinions.

But didn't we already do that? The Seaborn Panel did that for nine years.

Yes.

And didn't they demonstrate broad public acceptance by receiving interventions from only a miniscule fraction of the population, largely special-interest groups and quite a number of them professionals at that? Isn't broad public apathy a form of broad public acceptance, like that shown routinely for all forms of government policy in an open democracy?

Yes.

And so aren't we going to end up exactly where we started 40 years ago - storing high-level waste in safe, secure, monitored, retrievable configurations, without the express support of most of the population, and with an entire anti-nuclear cottage industry supported by the perception that a "final solution" is neither available nor possible?

Yes.

And what's wrong with telling the public that this waste is actually pretty good, as waste goes: solid, robust, self-contained, getting less toxic all the time, relatively small in volume, and not really hard at all to deal with? Why spend millions going around in circles, ignoring the fundamental truth, perpetuating the careers of snake-oil salesmen who have never demonstrated a willingness or ability to represent the best interests of the grass-roots population they bleed money out of?

You haven't learned a thing I've told you. I'm leaving.

And, for that matter, why hide the fact that "used fuel" is actually an energy resource for future generations? For heaven's sake, we're abdicating human ingenuity.

La la la la la la. I can't hear you.

CALENDAR

2004

June 6 - 9
25th CNS Annual 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

July 5 - 9
FIV 2004
8th Int'l. Conf. on Flow Induced Vibratios
Paris, France
website:
www.ladhyx.polytechnique.fr/fiv2004

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

Sept. 22 - 26
4th International Topical Meeting on Nuclear Plant Instrumentation, Control and Human Machine Interface Technology (NPIC & HMIT 2004)
Columbus, Ohio
website: www.ans.org

Oct. 2 - 6
11th International Topical Meeting on Nuclear Reactor Thermal Hydraulics (NURETH)
Avignon, France
email: nureth11@cea.fr

Oct. 3 - 6
Americas Nuclear Energy Symposium
Miami Beach, Florida
email: anes@hcet.fiu.edu
website: www.anes.fiu.edu

Oct. 3 - 6
CSChE 2004
54th Canadian Chemical Engineering Conference
Energy for the Future
Calgary, Alberta
website: www.csche2004.ca

Oct. 4 - 8
NUTHOS-6
Nara, Japan
Contact: Hisashi Ninokata
email: hninokat@nt.titech.ac.jp

Oct. 11 - 14
EPRI Int'l. Conf. on Water Chemistry of Nuclear Reactor Systems
San Francisco, California
email: cwood@epri.com

Oct. 11 - 14
EPRI International Conference on Chemistry of Nuclear Reactor Systems
San Francisco, California
Contact: Christopher Wood, EPRI
email: cwood@epri.com

Oct. 13 - 15
6th International Conference on Simulation Methods in Nuclear Engineering
Montreal, Québec
website: www.cns-snc.ca/simulation2004

Nov. 14 - 18
ANS Winter Meeting
Washington, D.C.
website: www.ans.org

2005

Mar. 9 - 10
CNA Annual Seminar
Ottawa, Ontario
website: www.cna.ca

Apr. 17 - 21
Monte Carlo 2005
Chattanooga, Tennessee
Contact: Bernadette Kirk, ORNL
email: kirkbl@ornl.gov

Apr. 25 - 29
5th Int'l. Conference on Isotopes
Brussels, Belgium
website: www.jrc.nl/5ici

May 8 - 11
National Conf. on Radioactive Waste Management, Decommissioning and Environmental Restoration
Ottawa, Ontario
Contact: M. Stephens, AECL
email: stephensm@aecl.ca

June 12 - 15
26th CNS Annual Conference and 29th CNA/CNS Student Conference
Toronto, Ontario
Contact: Denise Rouben, CNS
email: cns-snc@on.aibn.com

Nov. 6 - 8
7th CNS Int'l. Conference on CANDU Maintenance
Toronto, Ontario
Contact: Denise Rouben, CNS
email: cns-snc@on.aibn.com

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2004

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CNS WEB Page

For information on CNS activities and other links

http://www.cns-snc.ca


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