CANADIAN NUCLEAR SOCIETY

bulletin

DE LA SOCIÉTÉ NUCLÉAIRE CANADIENNE

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- First CANDU in China
- 22nd Simulation Symposium
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- PBNC 2002
- New Ways to Build ACR
- Isotopes at McMaster

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Cover Photo

The photograph on the cover is the most recent one available of the Qinshan project in China taken in September 2002.

(Photo courtesy of Keith Bradley, AECL, Beijing, China)

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EDITORIAL

Shades of Dickens

The events over the past few months bring to mind Dickens' famous opening, "It was the best of times, it was the worst of times". There have been notable achievements associated with the Canadian nuclear program but, unfortunately, also some major disappointments.

Top of the list of positive stories goes to the remarkable achievement of the team that saw the Qinshan III, unit 1 connected to the Chinese electrical grid in mid November, just 4½ years from the beginning of construction. Working half a world away in a different culture, with several international partners, the Canadian team brought the first CANDU unit in China on line, on budget, ahead of schedule. This should have been shouted from the rooftops but it is likely most Canadians are completely unaware of this Canadian success story.

Unfortunately, the public, at least in Ontario, are quite aware of the delays and budget overruns in bringing the Pickering A units back into service. In a remarkably candid talk in October (some excerpts are reprinted in the General News section) OPG's CEO Ron Osborne acknowledged that much of the problem was due to bad management. Perhaps this sad story might have remained largely unnoticed if the Ontario government had not played political football with the province's electricity system. Added to that we are now importing bad news about the crisis facing British Energy, which could seriously affect the future of Bruce Power.

Then there is the continuing sad story of MAPLE - a pair of small reactors being built at home, at our national nuclear laboratory - now some three years behind schedule.

The contrast behind the Qinshan success and the domestic failures demonstrates once again the importance of the "human" element. Over the past five decades a relatively small band of scientists, engineers and technicians developed, against great odds, a successful, indigenous, nuclear power system, as well as the best radioisotope production process in the world. The science and the technology are sound. Where is the management?

Nuclear energy offers great benefits, but it also presents hazards. From the beginning of the nuclear program, here and in most other countries, the latter was known, accepted and fully taken into account. Protection has been included in the technology but that technology must be applied and used responsibly. It is essential the nuclear community show that it can apply the great benefits of nuclear energy in a consistently responsible manner. If that were done and our political masters actually showed some wisdom, perhaps, just perhaps, nuclear energy could play its appropriate role in the ongoing energy versus environment debate.

Fred Boyd

IN THIS ISSUE

This issue of the *CNS Bulletin* highlights the achievement of Qinshan III, Unit 1, which began to produce electricity in November, just 4½ years after beginning construction. A paper given by Ken Petrunik, project director, to the PBNC 2002 conference, **Construction of CANDU in China: A China - Canada Success Story,** provides a very succinct summary of that remarkable feat.

Following a note on the 13th Pacific Basin Nuclear Conference, **Canada at PBNC 2002,** there is another paper from that conference, giving an overview of the Chinese nuclear program, **Peaceful Uses of Nuclear Energy in China.**

There is a short note on the **22nd CNS Simulation Symposium** held in Ottawa at the beginning of November. Other than an excerpt from Ralph Green's reminiscences of **The beginnings of the Simulation Symposia,** there are no reprints of technical papers from that very specialized Symposium on the basis that if the editor could not understand them many readers would have the same difficulty !

The paper **Steam Generator Life Cycle Management,** from the CNS International Steam Generator Conference in May had been intended for the last issue but withdrawn because of space limitations. As a change of pace there is a paper on **Isotope Production at McMaster Nuclear Reactor** first presented at the CNS Annual Conference. Another paper from the Annual Conference, from the special "historical" session, is **Procurement and Supply of CANDU Fuels.**

The final technical paper, **Advanced Construction Methods for ACR,** provides some details of the innovative approaches used in the building of Qinshan and further ones proposed for the Advanced CANDU Reactor.

Most of the items in the **General News** section, this issue, are Canadian, but, some may not have crossed your path.

There is, of course, news of some of the activities of your Society in the **CNS News** section. That is followed by notes on a few recent publications of possible interest and the updated **calendar.**

Finally, but definitely not least, is Jeremy Whitlock's special view of events in **Endpoint.**

As always we hope you will find something of interest and invite your feedback.

Construction of CANDU® in China
A China-Canada Success Story

by Kenneth Petrunik[1]

Ed. Note: The following paper was presented at the 13th Pacific Basin Nuclear Conference in Shenzhen, China, October 22, 2002. Implied but not explicitly stated in the paper, Qinshan III unit 1 achieved first criticality on September 20, 2002.

Abstract

Qinshan III CANDU® Nuclear Power Plant consists of 2 x 728 MWe units constructed by Atomic Energy of Canada Limited (AECL) and the Third Qinshan Nuclear Power Company Ltd. (TQNPC) at Qinshan in Zhejiang Province, P.R. China. The Contract Effective Date was 1997 February 12 and first containment concrete for Unit 1 was 1998 June 8. The scheduled in-service dates are Unit 1, 2003 February 12 and Unit 2, 2003 November 12. Construction and commissioning are on schedule and major project milestones have been met.

Qinshan Unit 1 is the first CANDU® in China and has been constructed to the shortest construction schedule of any nuclear power plant built in China. The reasons for this are modern project management tools and construction methods that included heavy lifts and modularization, together with an excellent working relationship and partnership between the Chinese and Canadian project participants. This paper describes the status of work, successes achieved, special experiences and looks ahead to the successful completion of the Project.

1. Introduction

TQNPC and AECL have forged an effective partnership in the construction and commissioning of the 2 x 728 MWe CANDU® station located on Hangzhou Bay at Qinshan, Zheijiang Province, P.R. China. The two units form part of an impressive nuclear complex that has two units operating and three under construction. The Reference Plant design is the design of Wolsong 3 and 4 CANDU 6 units in the Republic of Korea, for which TQNPC has implemented specific design improvements. Qinshan III is an international project with financing of the respective scopes coming from China, Canada, Japan and U.S.A.

2. Major Participants and Roles

AECL is overall project manager, designs and supplies the Nuclear Steam Plant (NSP) and manages NSP construction. (NSP equipment supply is subcontracted, in part, to Canadian, U.S., European and Korean suppliers.) TQNPC as owner manages the Balance of Plant (BOP) construction and executes commissioning. Construction is by Chinese Construction Contractors: China Nuclear Industry 23rd Construction Company (CNI 23), Hua Xing Construction Company (HXCC), China Nuclear Industries 22nd Construction Company and Zhejiang Thermal Power Construction Company. A consortium of Hitachi/Bechtel provides BOP design and supply under subcontract to AECL.

TQNPC's role includes: prepare Site; provide permanent site facilities (offices, warehouse) at start of construction for improved productivity; manage BOP construction by subcontract to Shanghai Nuclear Engineering and Research Institute, with technical assistance by Hitachi/Bechtel; provide local staff to AECL Site Project Management Organization; manage licensing; provide Quality Surveillance (QS) of NSP and BOP offshore equipment during manufacturing; provide added site QS of NSP construction through an independent QS company; execute commissioning with guidance and direction by AECL and provide fuel after the first fuel load. China has established the capability of manufacturing CANDU fuel. AECL's role covers: overall project management; design and supply of NSP equipment; site management by subcontract with Canatom NPM (Canada); training by a subcontract to Hydro-Quebec (Canada) Gentilly 2 CANDU® 6 station; design and supply of BOP equipment by a subcontract with Hitachi/Bechtel (Japan/U.S.A); NSP construction and site excavation by subcontracts to Chinese Construction Contractors; supply of initial load of fuel and heavy water, and guiding and directing commissioning.

1 Dr. Kenneth Petrunik is vice-President and Project Director with Automatic Energy of Canada Limited at Qinshan, Zhejiang, P.R. China

3. Project Management Tools

The Project features state-of-the-art engineering tools: three dimensional Computer Aided Design and Drafting System (CADDS); an Integrated Electrical and Control (IntEC) database for wiring, cable, connection and equipment information, which have been successfully used by CNI 23, the nuclear installation contractor and Commissioning; the CANDU® Material Management System (CMMS), which identifies and tracks equipment and material from the design phase through the supply chain, to construction and operation of the station; Asset Information Management (AIM) which manages, on line, all formal project records in electronic format; TRAK, an electronic document control system; a Weld Information System (WIS) developed by CNI 23 to electronically record quality information of all pipe welds; Primavera P3 , a planning and scheduling tool. These tools are integrated for maximum benefit and efficiency.

Design information in CADDS and IntEC has been integrated with other AECL electronic management systems for controlling and managing materials and documentation. Material and equipment information extracted from CADDS and IntEC carries a stock code number designation and a physical description that are linked with CMMS to produce bills of material. Accurate material identification is achieved, which is particularly important for materials requiring quality assurance documentation and traceability. The material in CMMS is bar coded for inventory control and allows the construction contractors to produce construction work packages by area. AIM provides real-time access to official drawings and documents by all parties, thus improving quality and efficiency and reducing costs. A key feature of AECL's production of electronic design documents is electronic approval of documents, which means that project official records can be completely electronic. TRAK accesses information from AIM to facilitate the scheduling, issue, distribution and shipping of documents and drawings (including those from suppliers). Real-time status reports and documents are accessible to all project participants at Site and in Canada through Local Area Networks (LAN) and by digital communications to off-shore locations.

TQNPC as owner supported the use of the new electronic tools, which has contributed to the successful management of the Project. The simplification of storage, accessibility, and upgrading facilitates configuration management from design to construction and operations – all to the benefit of Project stakeholders.

4. Construction

Construction of the plant is by Chinese contractors. Excellent co-operation among AECL, TQNPC and Chinese contractors has resulted in the introduction of modern construction management techniques, some of which were not previously used on other CANDU® projects. China is a large country and with an intensive nuclear power plant program, experience and personnel from Daya Bay were not readily available to Qinshan III. AECL's decision to place in its construction team "hands-on" construction specialists successfully provided "on-the-job-field" training, which greatly contributed to the success of the project. The introduction of new techniques was achieved by marrying conventional AECL practices with working experiences in China.

Open top construction was implemented for the first time on a CANDU® Project by TQNPC and AECL with a Very Heavy Lift (VHL) crane (Liebherr 1650/1800) supplied by TQNPC which provided schedule flexibility and reduced labour, and allowed work access from top and bottom. More than 70 lifts were made using the VHL crane and major lifts (metric tons including lifting gear) included: Steam generator – 220; Temporary roof – 150; Pressurizer – 103; Reactivity Mechanism deck – 43; Feeder Header frames - 40 each; Condenser shells - 270 each, and Turbine Generator stator – 280. AECL will continue to optimize and further exploit open top construction based on the Qinshan experience. Together with heavy lifts, the construction at Qinshan continues the successful evolution of CANDU® 6 design by Chinese contractors and AECL through modularization (dousing steel, piping, valves and electrical, lower dome steel formwork and spent fuel transfer assembly).

TQNPC has responsibility for BOP construction management. A key feature of the site was four undersea intake cooling water ducts averaging 50 meters long that were constructed in water having a high silt content and with current velocities reaching 4 meters per second with the daily inflow and outflow of the tide into Hangzhou Bay where the Qinshan site is located. This very difficult work was completed by TQNPC and Chinese contractors to support the project schedule.

A special challenge on Qinshan III was the small site with water on three sides. Some of the site area had to be created using retaining walls, which limited space especially in the first part of the project, and the restricted access required detailed planning and coordination of common systems in the ring trenches around the site to meet the schedule. Another success of the Chinese-AECL team was the achievement of the lowest leak rate recorded for a CANDU® 6 containment from the Unit 1 Reactor Building leak rate test. Lessons learned will reduce this even further on the second unit. The learning experience was visibly demonstrated in going from Unit 1 to Unit 2, with construction durations for many Unit 2 activities being significantly lower than for Unit 1.

5. Quality

AECL's Quality Assurance Program at site was implemented to meet both ISO 9002 and Canadian Standards Association requirements. AECL's construction contractors have implemented quality programs to international standards and used quality trend analysis to improve their work. An excellent working relationship was established between TQNPC and AECL using joint audit/evaluation teams, which gave better problem resolution and synergy. AECL has carried out over 100 audits on the project to continuously place quality as its first requirement.

6. Commissioning Team

TQNPC (1000 staff) executes commissioning with AECL (46 expatriate advisors) providing guidance and direction. Two hundred and thirty-two TQNPC staff were trained at Gentilly 2 NPP in Canada. AECL has provided a full scope CANDU® 6 simulator on site to support the training of operators who are licensed by the Chinese regulator, NNSA. The TQNPC commissioning team has quickly absorbed and applied commissioning/operations skills. The key factor in the commissioning of Qinshan III is the use of Canadian management processes and procedures to specify, document and verify the individual steps in the commissioning program. TQNPC and NNSA have effected a smooth licensing process supported by the quality, comprehensiveness and detail of the commissioning procedures and processes.

New Record for Chinese NPP Construction

Unit	First Concrete to Criticality (Months)	Criticality (Year)	First Concrete to 100% Power
Qinshan I	77	1991	87
Qinshan II Unit 1	66.5	2001	70
Daya Bay Unit 1	71.5	1993	75.5
Daya Bay Unit 2	69.5	1994	71.5
Lingao Unit 1	56.5	2002	59.5
Lingao Unit 2	55.5	2002	—
Qinshan III CANDU Unit 1	51.5	2002	

7. Schedules

The Qinshan CANDU® project represents the first CANDUs® constructed in China and with Qinshan Phase III being built on a small site surrounded by water on almost three sides, detailed planning and strong project management are required. The heart of this planning and management is a detailed 8500-activity Level 2, or Project, Coordination and Control schedule that sets the work requirements of all major Project participants and includes design deliverables, equipment deliveries, and construction and commissioning activities. The Level 1, or Contract schedule has 76 milestones. Level 3 schedules were produced by the Chinese Construction Contractors.

The following world records were set by Chinese NSP Contractors CNI 23 and HXCC, including:

- Slipforming Unit 1 — 18 days
- Slipforming Unit 2 — 14 days
- Fuel Channel installation Unit 1 — 69 days
- Fuel Channel installation Unit 2 — 64 days
- Steam Generator installation — 8 hours
- Pressurizer installation — 8 hours

8. Current Status

Unit 1 is at month 52.5 of construction. Owner's staff is about 1300. Contractor direct site labour force is at 3500 (down from 8000 peak). AECL and its off-shore subcontractors have 140 expatriates on site (peak of 180). Civil work is largely complete. Unit 1 commissioning is 90% complete and in Unit 2, turnovers from construction to commissioning are 95% complete. Project milestones to date have been met.

9. Summary

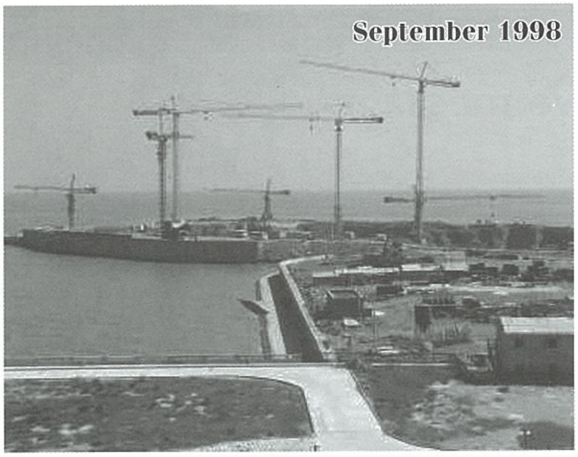
The China-Canada partnership has successfully integrated the multi-national project expertise of the participants on the Qinshan CANDU Project and has evolved CANDU® 6 construction methods and design. Advanced project management methods and tools have been adopted by TQNPC and Chinese Construction Contractors. Improved construction technology, coupled with hard work, has achieved many installation world records. TQNPC and AECL are working together to achieve a world construction schedule record for the first-of-a-kind NPP in any country – 51.5 months from first concrete to criticality and 54 months from first concrete to 100% power (forecast December 2002).

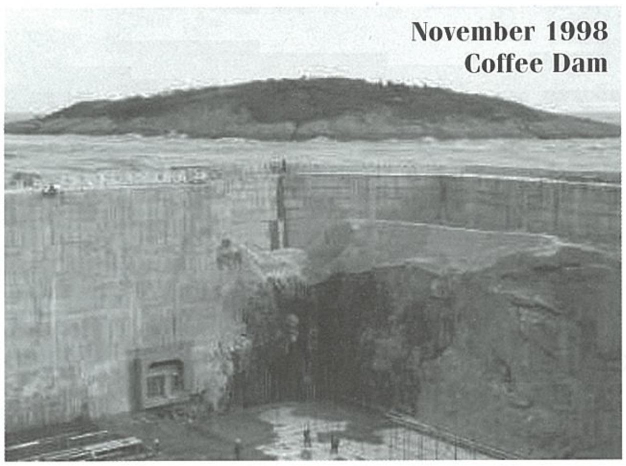
Qinshan III will become the future CANDU® 6 international reference plant and its construction advances will allow continued improvements for future "replicated" and "evolved" (enhanced modularization) units. Based on applying the lessons learned on Qinshan III, future CANDU® 6 units can achieve first concrete to 100% Power in 51 months, at a unit cost less than US1500/kW.

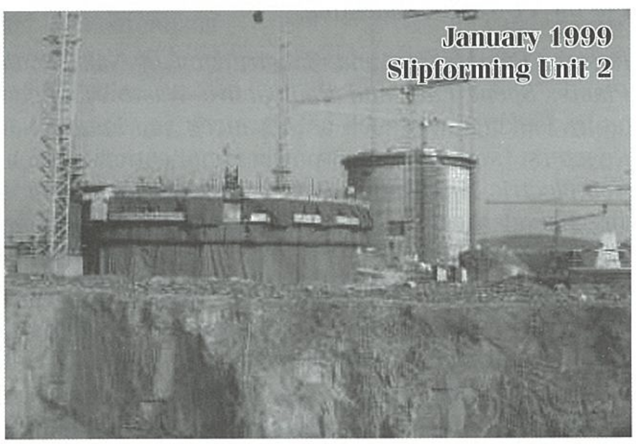
AECL and its Chinese partners will continue their long-term nuclear co-operation in China and will look for opportunities to work together internationally.

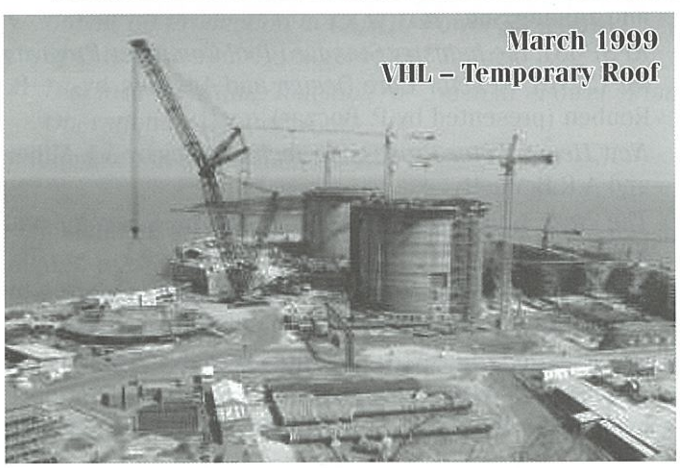
The accompanying photographs provide a visual impression of the progress of construction from September 1998 to September 2002.

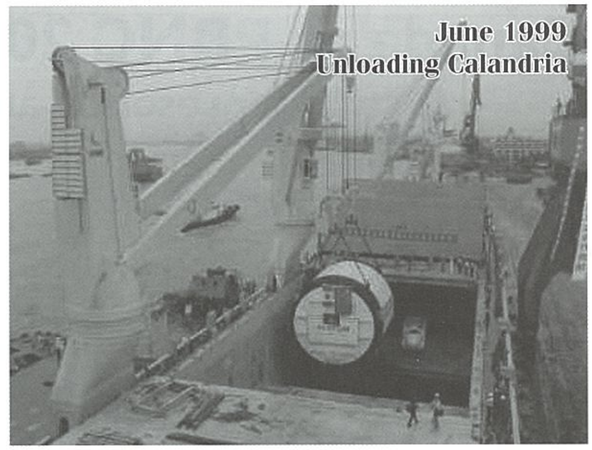
- *September 1998 — Site View*
- *November 1998 — Coffer Dam*
- *January 1999 — Slipforming Unit 2*
- *March 1999 — VHL – Temporary Roof*
- *June 1999 — Unloading Calandria Unit 2*
- *December 1999 — Site View*
- *April 2001 — Site View*
- *September 2002 — Site View*


September 1998

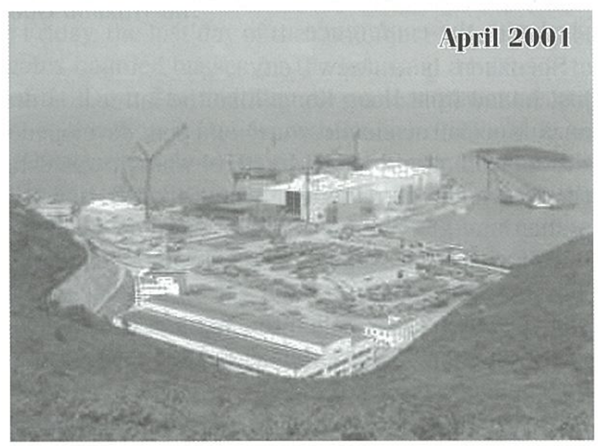

November 1998
Coffee Dam

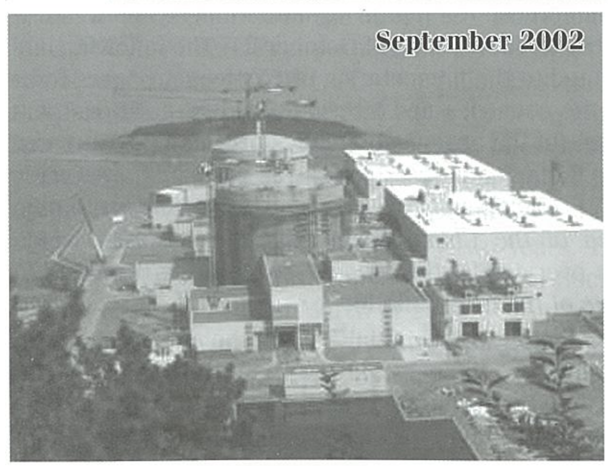

January 1999
Slipforming Unit 2


March 1999
VHL – Temporary Roof


June 1999
Unloading Calandria


December 1999


April 2001


September 2002

Canada at PBNC 2002
– A strong presence and positive message

Canada (primarily Atomic Energy of Canada Limited) had a strong presence at the 13th Pacific Basin Nuclear Conference (PBNC 2002) held in Schenzhen, China, October 21 to 25, 2002, and, with the criticality of Qinshan III, unit 1, only a few weeks earlier, Canada had a very positive story to present.

About 520 registered for the conference, close to half of whom were from China. The Canadian contingent numbered 30 and presented 16 papers. In addition, the AECL booth was undoubtedly the most impressive one of the modest exhibition associated with the conference.

The Wuzhou Guest House, venue of the PBNC 2002 meeting.

Shenzhen is a "new" city just inland from Hong Kong. Like the latter it is designated as a "special economic zone" and has developed many of the same characteristics. In 1979, when it was established, the area had a population of about 40,000. Now it is over 4 million and growing rapidly with many tall and impressive buildings, broad avenues, and crowds of cars rather than bicycles as in most of China. The conference was held in a new, five star, hotel called the Wuzhou Guest House which has its own golf course but is located some distance from the commercial part of the city.

PBNC 2002 formally began with the opening of the exhibition and a reception (featuring both Chinese and western delicacies) on the evening of October 21. The following day was devoted to the presentation of 15 plenary papers from each of the countries and international organizations participating. (In the absence of AECL's president, Robert Van Adel, the Canadian plenary paper was given by Gary Kugler of AECL.) *The opening plenary paper by Huazhu Zhang, chairman of the China Atomic Energy Authority, which gives an overview of the Chinese program, is reprinted in this issue of the* CNS Bulletin.

Some 244 (out of an initial 280) technical papers were crowded into two intensive days with six parallel sessions. The session topics embraced the full scope of nuclear activities, including: *Nuclear Safety and Regulation; Design, Engineering and Construction of Nuclear Power Plants; Spent Fuel and Radioactive Waste Management*; future looking ones such as *Advanced and Future Nuclear Reactors*; some on non-power applications, such as: *Non-electric Applications of Nuclear Reactor*; and some directed at the international community; *Promotion and International Cooperation of Nuclear Energy* and *Public Relations and Communication of Nuclear Energy.*

Following are the Canadian papers:

- *Sustaining the Future: The Role of Nuclear Power in Meeting Future World Energy Needs* by Romney Duffy and Yuliang Sun
- *RFSP-IST, the Industry Standard Tool Computer Program for CANDU Reactor Core Design and Analysis* by B. Rouben (presented by P. Boczar)
- *New Heavy Water Processing Technologies* by A.I. Miller and A.R.Bennett
- *The Next Generation CANDU Design* by S.K.W.Yu and K.R. Hedges
- *Application of PSA to CANDU Design and Licensing* by P.M. Matthew, W.C.H. Kupferschmidt and M. Bonechi
- *Construction of CANDU in China** by K.J. Petrunik
- *Advanced CANDU: Technology for a Sustainable Future* by J.M.Hopwood, M.Soulard and K.R.Hedges

A view of initial speakers at opening ceremonies of PBNC 2002 in Shenzhen, China, October 22, 2002.

- *CANDU Advanced Fuels and Fuel Cycles* by P.G.Boczar, G.Dyck, H.Chow, J.D.Sullivan, D.S..Cox, W.W.R.Inch, and P.J.Fehrenbach
- *Radioactive Waste Management at AECL* by R.D.Gadsby and C.J.Allen
- *The Advanced CANDU Reactor: Innovations in Reactor Physics for Next CANDU Generation* by J.Hopwood, P.Chan and .Boczar
- *Advanced Construction Methods in ACR®* by M.Elgohary, E.Choy, and S.W.Yu
- *Assisting Utilities in Achieving, Maintaining and Extending Excellence in Operation* by P.Tighe, B.Kakaria and S.Azeez (presented by B. McTavish)
- *MAPLE Reactors for Secure Supply of Medical Isotopes* by G.R.Malkoske and J.-P. Labrie
- *Cobalt 60 Production in CANDU Power Reactors* by G.R.Malkoske, J.L.Norton, and J.Slack
- *Distance Learning/Teaching of Nuclear Power Plant Operation* by G.T.Bereznai

* Reprinted in this issue.

In addition, there were a few Chinese and Korean papers related to CANDU. AECL handed out from their booth CDs with English and Chinese versions of the Canadian papers.

The major social function was the Conference Banquet held on the Wednesday evening. This featured a nine-course Chinese meal accompanied by traditional and modern entertainment. Interspersed with the entertainment was a brief ceremony marking the change of officers of the Pacific Nuclear Council, the authorizing body for the PBNC meetings. *(See separate article on the PNC meeting.)*

On the Friday, the last day of the conference, about half of the delegates boarded busses for the hour and a half ride to the site of the Daya Bay and Ling Ao nuclear power plants. Daya Bay is a two unit station with French PWRs built in the mid 1990s primarily to supply Hong Kong. Ling Ao is a new similar two unit station built on the same site where the second unit is in commissioning. Despite the different names the four units will be operated by a common organization.

Following a tour of the Ling Ao station, the closing ceremonies were held in a conference room at the site. Then delegates enjoyed a Chinese buffet lunch before returning to Shenzhen.

This was the second PBNC held in China. The first, PBNC 6, was in Beijing in 1987. The attendance was smaller than the last two conferences, perhaps still reflecting the tragedy of September 11, 2001. (The Canadian hosted PBNC in Banff in 1998 drew close to 800.) The US delegation numbered only 37. (The USA does not have nuclear relations with China.). Japan had the largest foreign attendance with 68, followed by France with 52 and Korea 37.

The PBNC meetings are held every two years. The next one will be sponsored by the American Nuclear Society and will be held in Hawaii in March of 2004.

Copies of the CD with the Canadian papers presented at PBNC 2002 are available on request. Contact: Ms. Qu Jiahong, AECL Shanghai Representative Office, e-mail: < qujiahong@spmo.com >

Peaceful Uses of Nuclear Energy in China

by Zhang Huazhu

Ed. Note: *Zhang Huazhu is Chairman of the China Atomic Energy Authority, the senior policy organization in China. The following is extracted from his opening address to the 13th Pacific Basin Nuclear Conference in Shenzhen, China, October 22, 2002.*

I. The Present Situation of Nuclear Energy Development in China

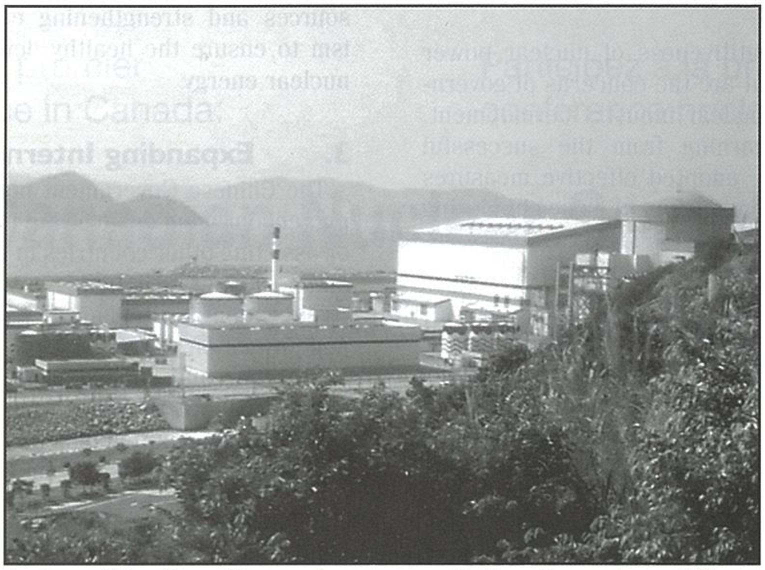
The Chinese nuclear industry embarked on a new road of development, and nuclear power development and nuclear technology application became the key orientation of the nuclear industry conversion in the early 1980s when the country introduced the policy of reform and opening-up. China's nuclear industry has been open to international cooperation based on self-reliant development ever since. With more than 20 years' development, nuclear science and technology studies have made continuous progress, nuclear power construction scored tremendous achievements, and nuclear technology application realized initial industrialization, contributing to the national economic development and improvement of people's livelihood.

China's nuclear power construction started in the early 1980s. Three units with a total installed capacity of 2100 MW were put into operation in the first half of 1990s in the mainland of China. Nuclear power accounted for around 1% of the total electricity generation of the country by the end of 2001. With the commercial operation of Unit 1 of Qinshan Phase II and Unit 1 of Lingao NPP this year, the total installed capacity of nuclear power increased by 1600 MW. Unit 1 of Qinshan Phase III and Unit 2 of Lingao NPP are now in the final commissioning stage. The other four units under construction are progressing successfully and will be put into operation respectively from 2003 to 2005, when the total installed nuclear power capacity in the mainland will reach 9,000 MW, supplying about 3% of the total power generation of the country.

Nuclear power alleviated the power supply shortage in China's coastal region and helps promote the local economic development. The volume of radioactive fluid and solid wastes discharged from the nuclear power plants since they were put into operation more than 10 years ago is far lower than the national standards, and the radiation to the surrounding environment has been maintained at the level of natural background. The operation of these plants caused no adverse effects to the environment, a proof to the success, safety and reliability of nuclear power in China, providing experience and laying down a solid foundation for its further development.

China's nuclear fuel industry, consistent with the nuclear power construction, has gained considerable progress. Its capability and level scaled a new height with technology upgraded through independent development and international cooperation. The manufacturers have achieved the localization of fuel assembly fabrication for light water reactors and CANDU reactors and are able to fabricate deep-burn-up fuel assemblies to meet the requirement of the 18-month reloading cycle of 1000 MW NPPs. Technology upgrade or significant progress has been achieved in other links of fuel cycle, which cut down the production cost of nuclear fuel and guaranteed further development of nuclear power.

Nuclear technology application has made substantial development in industry, agriculture, medicine and other fields in China ever since the country adopted the policy of reform and opening-up. There are more than 300 enterprises and institutions engaged in nuclear application technology development and production with a total annual output of 15 billion yuan RMB. The industrial electron accelerators and Cobalt sources installation maintained a yearly growth rate of more than 20% since 1990, one of the fastest in the world. Nuclear technology application development has yielded significant achievements and its industrialization process speeded up. The successful development of X-ray customs container inspection system, mails electron-beam sterilizers provide new effective means against smuggling and terrorism. Nuclear technologies are applied widely in various agricultural fields and have brought remarkable beneficiary effects to the economy, society and ecology. China, with a rapid development momentum of nuclear medical appliances, has 7 radioactive medicine manufacture bases and more than 1000 hospitals with nuclear medicine technology. The popularization and promotion of nuclear medicine contributed to improving the people's health level.



A view of the Daya Bay nuclear power station, Guangdong, China.

2. Moderate Development of Nuclear Power and Pushing Industrialization of Nuclear Technology Application

The Chinese Government attaches great importance to and fully supports the development of peaceful uses of nuclear technology and related industries. We encourage enterprises to make full use of the domestic and international markets and resources to develop and expand the scale of nuclear energy industry and improve technology so that it will play an increasingly important role in the national economic construction.

The development of nuclear power which is safe, clean, and economical, is of growing importance to diversifying China's energy mix, improving energy security, developing energy uses, and promoting sustainable development.

The Chinese Government has ratified the Kyodo Protocol. While raising the energy efficiency, we are making efforts to increase the proportion of clean energy. Nuclear power, a clean energy suitable for scale production with proven technology, will have greater development space in China as its economy continues to grow and its people's livelihood further rises. In the eastern coastal area with comparatively developed economy in particular, nuclear power will become an important option to optimizing energy mix and alleviating pollution.

With the guideline of "moderate development of nuclear power", the competent authorities are positively drafting and implementing nuclear power development plans for coordinated development. China's nuclear power construction will follow the principle of "cooperating with international partners with China playing the major role, introducing technology and promoting localization" and realize "self-reliance and standardization". The goal is to attain independence in designing, manufacturing and operating large nuclear power units on the basis of learning advanced experience of other countries, and to further cut down the capital cost and operation cost of nuclear power for sake of higher competitiveness.

China's nuclear energy application, like in many other countries, develops in "three steps" (i.e.: from thermo neutron reactors to fast neutron breeding reactors and then to controlled fusion reactors). Development and application of thermo reactors dominants at present and will do so in a long time to come, while technology research on fast reactors and fusion will be carried on concurrently. We will actively participate in international cooperation and follow the development trend of the world. Development strategy for thermo nuclear reactor technology is phased as follows: applying proven nuclear power technology for units constructed before 2010 while continuing research on advanced PWR and high temperature gas cooled reactor, and developing advanced technology with independent intellectual property rights; adopting advanced reactor types according to the international trend of nuclear power technology development after 2010 to further improve its safety and economics.

The nuclear fuel industry development shall cater to both the demands in the near future and the requirements for long-term development. Its development shall parallel that of nuclear power, increase manufacture efficiency and reduce cost. China will mainly rely on its own for nuclear fuel supply, but not excluding the possibility of using resources of other countries in light of the domestic production capabilities and the demand-supply situation of the international market. Spent fuel from NPPs is planned to be reprocessed in China to make full utilization of uranium. A pilot spent fuel reprocessing plant is under construction and research work of deep-underground disposal of high-level radioactive waste is active.

Enormous efforts have been devoted to the nuclear technology application to push forward technology innovation, develop quality products of new generation, support projects on energy saving, environmental protection and life sciences, and make breakthroughs in key technologies. Nuclear technology will be more extensively applied in fields of agriculture, medicine, environmental protection and security, oriented by market. Its industry scale and technology level will be improved to fully play its role in settling issues concerning agriculture, ecological environment, hydro-resource management, medical care and health.

The safety, economic competitiveness of nuclear power and nuclear waste management are the concerns of governments and public related to nuclear industry development. The Chinese Government, learning from the successful experience of other countries, adopted effective measures to settle the technological and management issues hindering further development of nuclear power by improving its economics at the prerequisite of safety and reinforce radioactive wastes management.

Nuclear safety is the lifeblood of nuclear industry development. The Chinese government adheres to the principle of "safety and quality come first" and gives top priority to safety of nuclear industry, and has adopted all effective measures to ensure the health of the staff and public and protect the environment. China's nuclear industry has maintained good record of safe operation and environment protection for decades with no serious incidents. A fairly complete nuclear safety management system, nuclear safety monitoring system and nuclear emergency working system have been set up according to international practices, which played a positive role in ensuring safety.

Improving the economics of nuclear power is vital to nuclear energy development under the prerequisite of safety. More than 10 years of China's experience shows that nuclear power has brought about beneficiary economic and social results by alleviating power supply shortage in the southeast coastal area at a lower generation cost than anticipation. The capital cost of the 4 NPPs under construction has been cut down by a big margin through effective control of "quality, timetable and investment" and other strict engineering management. The specific investment of Qinshan Phase II with high self-reliance is distinguishingly lower than the unit introduced from other counties in the same period, and its economic factors competitive against other clean energies.

Improving nuclear power economics is all the more urgent with the energy development and furtherance of institutional reform in the sector of power in China. Capital cost will be further reduced in the future. We are convinced that increased self-reliance and production scale will further cut down the cost and improve the economic competitiveness of nuclear power.

The Chinese Government attaches great importance to radioactive waste management and has adopted effective measures to cut down its production from NPPs and other nuclear facilities according to international experience. Policies and technology guidelines have been identified to dispose solid waste from nuclear power plants in the regional repository after interim storage. Two near-surface repositories fro low-and-intermediate level radioactive waste have been built in Guangdong and Gansu. High level wastes will be disposed in deep geological repository, and relevant studies are under way.

The Chinese Government pays great attention to the physical protection of nuclear facilities, nuclear materials and radioactive sources and has adopted feasible measures including reinforcing management on waste radioactive sources and strengthening efforts against nuclear terrorism to ensure the healthy development of peaceful uses of nuclear energy.

3. Expanding International Cooperation

The Chinese Government pursues a policy of not advocating, encouraging or involving in nuclear weapon proliferation or assisting other countries in nuclear weapons development; and positively participates in the international efforts at non-proliferation. We hold at the meanwhile that non-proliferation and promotion of peaceful uses of nuclear energy supplement each other and shall be given equal attention. Proceeding from the above-mentioned position, China actively develops cooperation of mutual benefit with other countries and makes due contribution to both causes.

China has signed agreements on cooperation of peaceful uses of nuclear energy with US, UK, France, Russia, Japan, ROK, Canada, Pakistan, Vietnam, Egypt and others under the principle of mutual respect of sovereignty, equality and mutual benefit, which paved the way for bilateral exchange and cooperation in the nuclear sector.

China carried out cooperation in various forms with many countries, especially countries in the Pacific region, including personnel exchange, transfer of equipment and technology, economic trade, etc. For example, China made fruitful cooperation with France, Russia, Canada and Japan in nuclear power plant construction.

China, a developing country with nuclear industry capability, assists other developing countries within our ability, the demonstration of which is the Chashma NPP successfully constructed with cooperation between China and Pakistan. China actively participated in RCA projects and other activities under the framework of FNCA, and contributes to the cooperation and common development of this region.

Concerning multi-lateral cooperation, China actively participates in IAEA activities. China has been devoted to achieving the Agency's objectives of non-proliferation and promotion of peaceful uses of nuclear energy as stipulated in the Statute since its accession to the Agency in 1984. China also took part in the negotiations and drafting of international nuclear conventions, and has signed or acceded 12 international legal instruments including the Treaty on Non-Proliferation of Nuclear Weapons, the Convention on Physical Protection of Nuclear Materials, the Convention on Early Notification of Nuclear Accidents, the Convention on Assistance in the Case of an Nuclear Accident or Radiological Emergency, and the Nuclear Safety Convention. China strictly sticks to these conventions and faithfully performs its corresponding obligations. The additional protocol to the safeguards agreement between China and IAEA took effect last March, fully proving China's vigorous support to the international safeguards regime.

China's nuclear industry is facing new opportunities in the new century during which its nuclear power and nuclear technology application will attain further development. We are looking forward to cooperating with other countries in the nuclear sphere to make joint efforts for the benefit of the mankind.

McMaster University

ENGINEERING

CHAIR IN NUCLEAR ENGINEERING

The Department of Engineering Physics at McMaster University is pleased to announce that industrial funding via the University Network of Excellence in Nuclear Engineering (UNENE) has resulted in the potential for the establishment of an NSERC (Natural Sciences and Engineering Research Council) Industrial Research Chair in Nuclear Safety Analysis.

The role of the Chair will be to contribute significantly to the body of scholarship in nuclear engineering. Fields of relevance include state-of-the-art research in experimental methods and numerical and mathematical modelling in the disciplines of thermal hydraulics, reactor safety, reactor physics, and radiation physics. The incumbent is expected to establish a vigorous research program for contributing to knowledge in the field and developing and mentoring of graduate students. He/she will also be expected to teach and mentor undergraduate students as well as collaborate with the nuclear industry through UNENE. The tenure-track appointment to the Chair is expected to be at the rank of Professor or Associate Professor.

Applicants should have earned a Ph.D. in Nuclear Engineering, Engineering Physics, Physics, Mechanical Engineering, Chemical Engineering, or a closely related discipline. They should have industrial and/or post-doctoral experience, and have interest and demonstrated research expertise in nuclear safety analysis. Qualification to be registered as a Professional Engineer in the Province of Ontario, or become registered within three years of appointment, will be considered an advantage. McMaster University operates a 3 MW pool reactor dedicated to isotope production, research and teaching. This position offers the opportunity to interact with the existing nuclear programs in the department, with the other universities and industries in UNENE, and the programs at the McMaster Nuclear Reactor. For more detailed information on the Departmental activities, please consult our web page at http://engphys.mcmaster.ca.

Applicants should send a letter of application, a *curriculum vitae,* statements of teaching and research interests, a selection of research publications, and the names and addresses of at least three references to:

Dr. Paul Jessop
Professor and Chair
Department of Engineering Physics
McMaster University
Hamilton, Ontario
Canada L8S 4L7

The position is available immediately and applications will be accepted until the position is filled. Applications submitted by e-mail will not be accepted.

All qualified candidates are encouraged to apply; however, Canadian citizens and permanent residents will be given priority. McMaster is strongly committed to employment equity within its community, and to recruiting a diverse faculty and staff. The University encourages applications from all qualified candidates, including women, members of visible minorities, Aboriginal persons, members of sexual minorities, and persons with disabilities.

22nd CNS Simulation Symposium
– Specialists from four countries meet in Ottawa

Close to 50 analysts convened in Ottawa, November 3 to 5, 2002 for the 22nd CNS Simulation Symposium. Although most of the delegates were from Canada they were joined by associates from Argentina, Korea and the USA.

The first day was devoted to registration and a pleasant social hour in the evening. The actual meeting began the next morning with opening remarks from symposium chairman Dimitru Serghiuta of the Canadian Nuclear Safety Commission followed by some reminiscent remarks by Ralph Green, former vice-president at Atomic Energy of Canada Limited. He was instrumental in the creation of the first simulation symposium held in 1974. *(Excerpts from his talk are reprinted below.)*

Dimitru Serghiuta

Green was followed by Michael O'Neill, manager of nuclear safety at OPG's Pickering station, who gave another short "historical" presentation on *"30 Years of Reactor Physics at Pickering"*. O'Neill emphasized that experimental evidence is essential to validate the results of simulation analyses. When he commented that the fuel was still in the Pickering A reactors he was asked how it would be modelled for the restart. His reply was that they were still using the WIMS code but added the comment that it will be "interesting".

The plenary session concluded with a paper by Prof. Paul Turinsky, of North Carolina State University, on *"Adaptive Core Simulation"*.

The Symposium then broke into two parallel sessions, "Physics", and "Thermalhydraulics" which ran through most of the first day. In late afternoon there was a second plenary session at which Romney Duffy gave an extensive presentation on AECL's program for an advanced CANDU reactor entitled, *"From Concept to Market: The New ACR"*. He was followed by a short paper by Marcelo Gimenez from Argentina, on "Nuclear Reactor Conceptual Design: Methodology for Cost-Effective Internalisation of Nuclear Safety".

On the second day there were also sessions on "Safety", "Computational Fluid Dynamics" and "Instrumentation and Control". 35 papers were presented in the parallel sessions.

The symposium ended with a special plenary session at which former Carleton professor Terry Rogers presented a paper co-authored by Mohamed Lamari, who had earned his doctorate under Rogers and is now with the International Atomic Energy Agency in Vienna. The title of their paper was *"Application of CANDU Molten Core Model to RASPLAV Results"*. RASPLAV was an international scale experiment conducted in 1994 and 1997 on the interaction of molten "corium" with a water cooled lower head of a PWR pressure vessel. Rogers stated that their analytical model DEBRIS.MLT gave reasonable agreement with the experimental results for steady state. He noted that was the same code that had been used to show that a molten CANDU core would be contained in the calandria for more than 24 hours until the water in the shield tank boiled away.

An excellent dinner was held the Monday evening, with guest speaker Kevin Routledge, president of the new company Nuclear Safety Solutions Ltd. and of NNC Canada Limited, a subsidiary of NNC plc of the UK. He titled his talk *"Challenges Facing the UK Nuclear Industry"*. With the distorted market, where the wholesale price of electricity is below any generation cost, he commented that there is unlikely to be any new generation built in the UK for some time.

The organization of this Symposium was very thorough. Ample time was provided for questioning after the presentations and for general discussions during the mid morning and mid afternoon refreshment breaks. This "relaxed" schedule appeared to be appreciated by the delegates who do not have many opportunities to compare notes on a person to person basis.

(As an editorial footnote, this very specialized meeting had probably the highest percentage of PhDs of any nuclear gathering - about 65% in our reckoning. Just the titles of many of the papers were unintelligible to a layperson.)

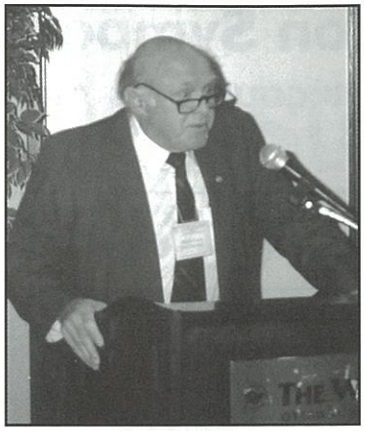
A CD was provided with most of the papers. It can also be purchased from the CNS office.

* * *

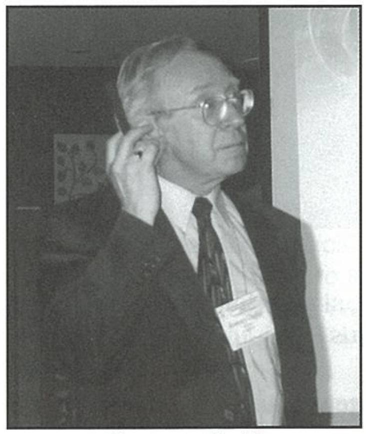
The beginnings of the Simulation Symposia

*The following is excerpted from the opening presentation by **Ralph Green** to the 22nd CNS Simulation Symposium.*

The beginning was back in the early 1970s. In October 1970 the Reactor Control Branch was formed at Chalk River, and I was one of its original members. One of the Branch's goals was to develop a dynamic model of a complete CANDU power station, from the reactor core right out to the electrical grid. Our approach was to develop an analog computer model since we wanted to look at things in real time, e.g. look directly at the power pulse during a loss-of-coolant accident, and also to be able to attach control devices to the model and to test various control strategies. To this end we acquired a fairly large analog computer, later known as the Dynamic Analysis Facility.



Ralph Green



Romney Duffy

I would remind you that at that time reactor control was an important issue, what with the Gentilly-1 reactor having a very large positive void coefficient, and there was concern about spatial power control in the larger CANDU-PHW reactors then being designed for the Bruce power station. Also, at that time major studies were undertaken at Chalk River to look at future CANDU reactor concepts, such as the CANDU-EBLW, a boiling-light-water cooled, enriched-uranium-fuelled CANDU, where the use of enriched uranium would enable a large reduction in the void coefficient and void effect, and the CANDU-BLW-PB plutonium burner, a reactor fuelled with uranium enriched with plutonium extracted from irradiated fuel. These reactors had nuclear parameters quite different from the natural-uranium-fuelled CANDU reactors, so there was work to be done to investigate the control and safety features of these new concepts.

Once we had the Dynamic Analysis Facility up and running a group of us in the Reactor Control Branch thought we should contact other groups in the industry working in the field in order to exchange ideas and compare approaches to tackling the control and safety issues of mutual interest. We approached people at Ontario Hydro, Sheridan Park and the Whiteshell Laboratories and this resulted in the first simulation symposium, held at Ontario Hydro in Toronto in 1974.

This first symposium was so successful that it was decided to hold similar meetings on an annual basis, with the various participating organizations taking turns hosting the meetings. Initially, there were just AECL and Ontario Hydro participants at the symposia, but we were soon joined by the other nuclear utilities, Hydro Quebec and New Brunswick Power, and the group from Ecole Polytechnique in Montreal. Later on, the Royal Military College and McMaster University became active participants in the process.

The symposia continued [in that form] until 1982, sponsored by the industry groups. There was no symposium in 1983, but in 1984 the Canadian Nuclear Society took over the sponsorship and has continued to this day.

The first twelve symposia were entitled Simulation Symposium on Reactor Dynamics and Plant Control, reflecting the fact that in the early days the emphasis was on control and safety issues. In 1987 the title became Reactor Simulation Symposium, and since 1989 has been Nuclear Simulation Symposium.

These name changes reflected the broader range of topics being addressed at the various symposia, e.g. flux mapping systems for spatial power control, fuel-management schemes, a broad range of thermalhydraulics calculations, reactor physics code development, advanced fuel cycles, plus many other areas.

When I looked at the program for this symposium, I was impressed at how far you have come since those early days, in two important aspects. Firstly, the very broad range of topics that is being addressed, and secondly, the international nature of the participation.

Even though the program has expanded greatly in scope, I see some familiar topics are still being tackled, such as the CANDU-PHW void coefficient, something I thought we had laid to rest many years ago with our measurements in the ZED-2 reactor at Chalk River. However, I understand that a committee has recently been carrying out a quality assurance exercise on that important reactor parameter. I also noticed that there were several papers related to CANFLEX fuel, something I was quite keen on before I retired.

I thank you for including me in your meeting and wish you great success in your deliberations.

Steam Generator Life Cycle Management: Ontario Power Generation (OPG) Experience

by C.C. Maruska[1]

Abstract

A systematic managed process for steam generators has been implemented at Ontario Power Generation (OPG) nuclear stations for the past several years. One of the key requirements of this managed process is to have in place long range Steam Generator Life Cycle Management (SG LCM) plans for each unit. The primary goal of these plans is to maximize the value of the nuclear facility through safe and reliable steam generator operation over the expected life of the units. The SG LCM plans integrate and schedule all steam generator actions such as inspection, operation, maintenance, modifications, repairs, assessments, R&D, performance monitoring and feedback.

This paper discusses OPG steam generator life cycle management experience to date, including successes, failures and how lessons learned have been re-applied. The discussion includes relevant examples from each of the operating stations: Pickering B and Darlington. It also includes some of the experience and lessons learned from the activities carried out to refurbish the steam generators at Pickering A after several years in long term lay-up. The paper is structured along the various degradation modes that have been observed to date at these sites, including monitoring and mitigating actions taken and future plans.

INTRODUCTION

Systematic Managed Process at OPG

At OPG nuclear generating stations the Steam Generator Program (SG Program) establishes the requirements for operation, maintenance, inspection, repairs, modifications and safety of nuclear steam generators. The SG Program was prepared in accordance with the guidelines provided by the Nuclear Energy Institute (NEI)[1] including the guidance and information provided through the Electric Power Research Institute (EPRI) and the recommendations of the International Atomic Energy Agency (IAEA)[2]. The SG Program incorporates recommendations regarding the management of steam generators and applies relevant internal and external experience. A major requirement of the SG Program is to have in place at all stations/units Steam Generator Life Cycle Management Plans (SG LCM Plans). The SG LCM plans are based on active and plausible degradation and integrate and schedule all steam generator actions or mitigating measures.

The SG LCM process has the primary goal of maximizing the value of the nuclear facility through safe and reliable steam generator operation over the expected life of the units. This is achieved by performing a comprehensive equipment degradation assessment, identifying contributing or detrimental factors, predicting future equipment performance and estimating remaining life. The SG LCM process prioritizes actions or countermeasures in terms of risks and threats to the unit (safety, reliability, and production) and takes into account the probable success of the various actions. The process serves as a long range planning tool and ensures long term cost-effective production of electricity.

The SG LCM process includes issue of unit/outage specific SG Outage Scope Plans, prepared about a year ahead of the planned outage and based on the requirements of the long range SG LCM Plans. These SG Outage Scope Plans detail all inspection, maintenance, repair and modification activities to be performed in the particular outage and are rigidly controlled before and during the outage. Results obtained during the outage, combined with other information such as engineering analyses or research & development results, are fed back into the SG LCM process in a continuous cycle (Plan - Do - Check - Adjust cycle). For more details see references 3 and 4. In addition to assuring component integrity, SG LCM Plan actions are also aimed at ensuring adequate thermal performance throughout the life of the plant.

At OPG there is a distinction made between the terms Life Cycle Management and Fitness-for-Service. The primary objective of both is the same; to assure the integrity of the steam generators as a primary system pressure and containment boundary. The difference between the two terms is in the time span of application. SG LCM applies, in theory, for the life of the unit, although practically it has a span of 5 to 10 years. Fitness-for-service applies for the next unit operating cycle, i.e. until the next scheduled inspection. The typical unit operating cycle at OPG could be from one to four years. *Figure 1* shows the distinction in the two terms as a function of the population of flaws. Fitness-for-Service manages the tail end of the flaw distribution while Life Cycle Management manages the bulk

1 Ontario Power Generation, Toronto, Ontario M5G 1X6

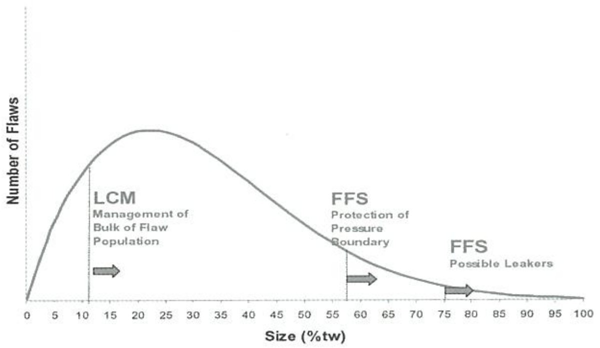


Figure 1 - Life Cycle Management vs. Fitness-for-Service at OPG

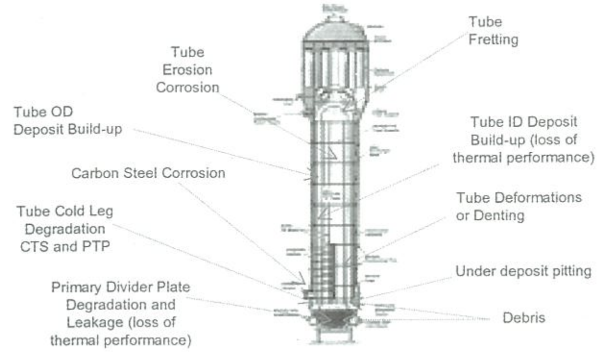


Figure 2 - Steam Generator Degradation Mechanisms at OPG

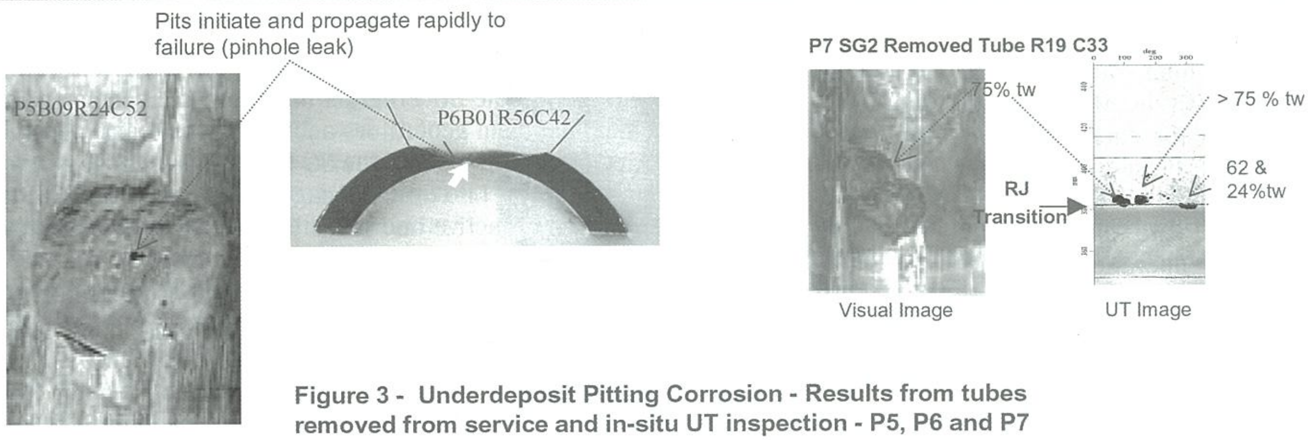


Figure 3 - Underdeposit Pitting Corrosion - Results from tubes removed from service and in-situ UT inspection - P5, P6 and P7

of the flaw population.

If degradation is severe and very advanced, then the two terms become indistinguishable. By this stage the unit is operating very uneconomically from outage to outage, probably experiencing frequent forced outages and there is no long term outlook and the remaining life of the steam generators is severely limited.

OPG Steam Generator Features

The steam generators at OPG are vertical, recirculating, U-tube heat exchangers. There are four steam generators per unit at Darlington and 12 steam generators per unit at Pickering Units 1 - 4 (A) and Pickering Units 5 - 8 (B). All have integral preheaters. Darlington steam generator tubing is made of nuclear grade Incoloy 800 with stainless steel tube supports (lattice bar tube supports and flat bar Anti Vibration Bars). Pickering A and B steam generator tubing is made of Monel 400 with carbon steel lattice bars tube supports at Pickering A and carbon steel tube supports (tri-foil broached hole plates and staggered scallop bar U-bend supports) at Pickering B.

Steam Generator Degradation Modes

OPG steam generators are currently experiencing a variety of degradation modes. *Figure 2* summarizes the type and location of all the degradation modes observed to date at Pickering A, Pickering B and Darlington. Tube pitting (or underdeposit pitting corrosion) is occurring at Pickering A and B, tube/support fretting at Darlington and Pickering A, tube deformations due to denting at Pickering A, tube erosion corrosion at Pickering B, tube cold leg thinning at Pickering A and B and tube failures due to debris at all stations. Other degradation includes carbon steel corrosion of internal components at Pickering A, tube ID deposit build up at all stations and Primary Divider Plate degradation and leakage at Pickering A and B; these latter cause degradation of the steam generator's thermal performance. The discussion below is structured along these degradation modes.

DISCUSSION

Tube pitting (active at PA and PB)

The main tube degradation mode, affecting all of the steam generators at Pickering B and to a lesser extent at Pickering A, is tube underdeposit pitting corrosion. The main contributing factor to this form of corrosion is the presence of porous adherent deposits. At Pickering B, tube corrosion is taking place under these deposits even in the most benign operating environments and is an ongoing

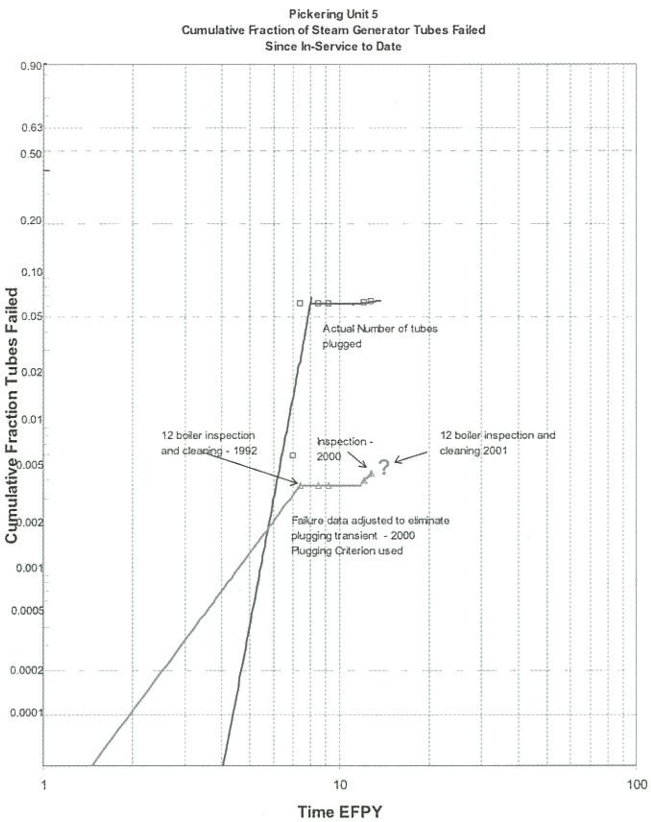
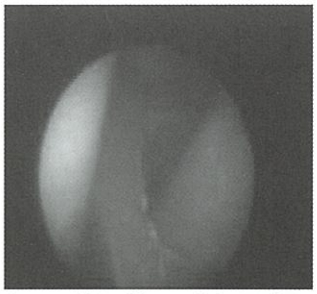
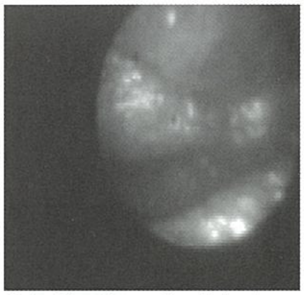


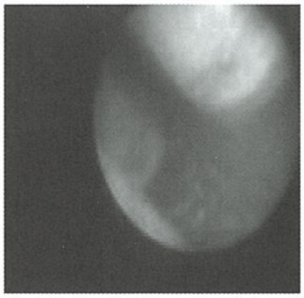
Figure 4 - Tube Under Deposit Pitting Corrosion - Number of Tubes Plugged vs. Time in P5



Support Plate 7 Lane 30 inspection with <1% blockage. This is typical in all lanes inspected at this Support Plate The LAN region appears very clean with no deposits.



Tube Sheet Lane 30 with hard deposits on tube surface and top of tube sheet. This condition is typical towards the middle of the tube bundle



Tube Sheet Lane 25 with minimal deposit. This condition is typical of the areas in the periphery tubes and lanes 15 and 20.

Figure 5 - Post WL and Chemical Clean Support Plate Inspection Results in P6 – Oct 2001

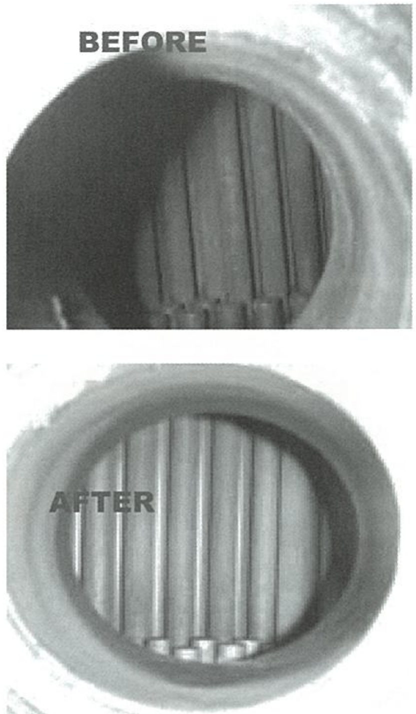
process. Other factors are a very susceptible material and adverse chemical conditions (such as oxygen levels). Tube pitting occurs in two distinct ways; a few "new" pits initiate and grow rapidly throughwall (causing forced outages due to tube leaks) and a few "old" pits propagate slowly. Deep pits have been observed to have a relatively consistent morphology with a very low aspect ratio and they could be described more accurately as localized wastage, see *Figure 3* for visual and ultrasonic images.

Under deposit pitting corrosion is occurring predominantly at the top of the hot leg tubesheet, but it can occur also at the 1st hot leg support. This poses two significant SG LCM challenges: detection and mitigation. Detection and sizing of flaws in the tubesheet area has proven to be a challenge for the basic Eddy Current bobbin probe and often requires deployment of alternate probes or techniques. The tubesheet area is also very difficult to access from a deposit removal perspective, waterlancing must clean deposits to the tubesheet in order to allow the cleaning chemicals to access the crevices. The more maintenance is delayed, the harder it becomes to remove the deposits.

Figure 4 depicts a Weibull plot of the cumulative number of tubes plugged as a function of time (in EFPY) at Pickering Unit 5 (P5). The blue (higher) line plots the actual number of tubes plugged. The green (lower) line plots the same data but using the current plugging criterion to remove the inspection/plugging transient. In 1991/92 tubes with pit indications were plugged almost on detection. Since 2000, through the application of the Fitness-for-Service Guidelines[5], a plugging criterion of 51% tw has been used. The application of this plugging criterion has reduced the proportion of tubes plugged to about 10X less than in 1991/92 and has saved hundreds of tubes which has extended the life of the steam generators considerably.

Three separate stages can be observed in the green (lower) line of Figure 4. Pitting degradation was active and growing in 1991/92 and close to 2000 tubes were plugged in this unit at this time. After the remedial actions were taken (waterlancing, chemical cleaning and improvements in the operating chemistry), there was a period of time with little or no degradation followed by a resurgence of pitting in 1998 when the first tube leak (post cleaning) was detected in P5 and subsequent leaks in the other units. The rate of pitting prior to 1991 appears very similar to the rate of pitting after 1998. Coincidentally, deposits had re-built in the boilers during the interval between 1992 and 1998.

Ideally, secondary side deposits should have been removed prior to the resurgence of pitting degradation and this maintenance had been properly scheduled in the SG LCM plans. Unfortunately, there were delays in the applica-



Process removed the corrosion and deposits and returned the boilers to their original silver-grey colour.

Figure 6 - Hot Boiler Chemical Cleaning Results - in P5, March 2001

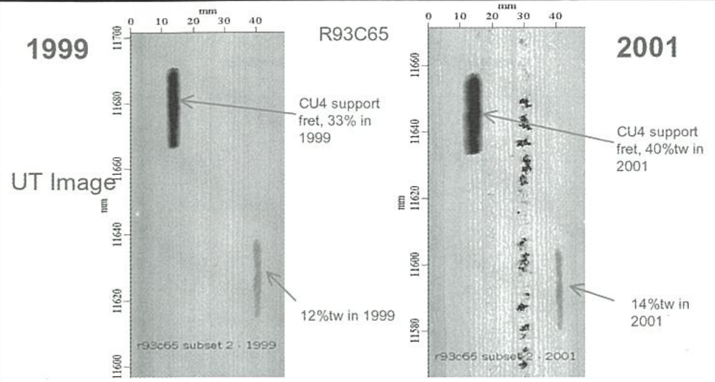


Figure 7 - Darlington Tube/Support Fretting

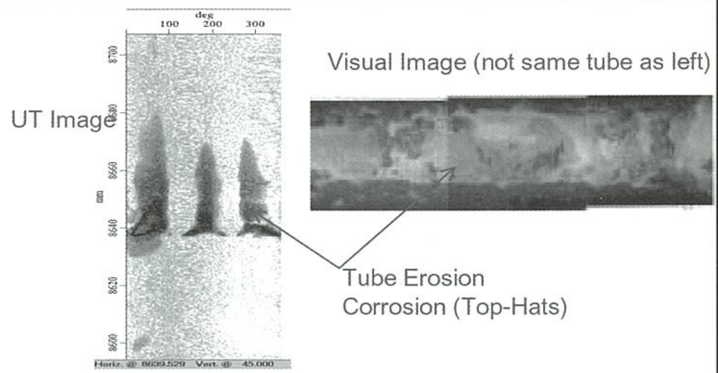


Figure 8 - Tube Erosion Corrosion (Top-Hats) in P8 UT in-situ Results and Visual Inspection Results on Tubes Removed from Service

tion of this essential maintenance and OPG has since paid a high price in the form of significant production losses due to frequent forced outages (multiple tube leaks have occurred at all Pickering B units in the last two to three years) and short uneconomic operating intervals. This resulted in a decision to implement an aggressive schedule of waterlancing and chemical cleaning of all Pickering B steam generators.

To date, 36 steam generators in 3 units have been cleaned in less than a year (2001/2002). The fourth unit (P7) is scheduled for deposit cleaning in early 2003. The visual inspection results post cleaning activities indicate that the maintenance carried out recently has been fairly successful at removing the deposits, although there were some areas near the tubesheet where some hard deposits were not removed, see *Figure 5* and *Figure 6*. It is hoped that this aggressive maintenance will once again result in mitigation of tube pitting. The SG LCM plans for each PA and PB unit now include regular waterlancing every four years and chemical cleaning every eight years.

Tube fretting (active at Darlington)

Tube fretting in the U-bend region, due to the interaction of the tubes with the Anti-Vibration Bar (AVB) supports, has been observed at all Darlington steam generators. To date, Eddy Current inspections have been carried out in respective Units 1, 2, 3, and 4 planned outages during 1999-2001and all 16 steam generators have been inspected in the area at risk (U-bend region).

Over 2200 frets in 943 tubes have been observed (combined results from all four units) and a number of frets have been detected in excess of 40% tw., requiring tubes to be removed from service. Frets have been observed to be regular in shape and relatively easy to detect and size with Eddy Current probe and Ultrasonic NDE technology, see *Figure 7* for ultrasonic images. At the projected rate of growth of the existing and anticipated frets, future tube removals by plugging will start affecting the thermal performance. To prevent this type of performance degradation, a retrofit fix (auxiliary flat bars of similar but thicker design) is planned to minimize the degree and extent of the fretting. The SG LCM has the first retrofit scheduled for 2003 at D4.

The other units will be modified in subsequent planned outages. For a complete description of this degradation mode and mitigating actions planned see reference 6.

Tube Erosion-Corrosion "Top Hats" (active at PB)

Wall loss degradation has been observed on the outside diameter (OD) of the tubes at the hot leg tre-foil broached

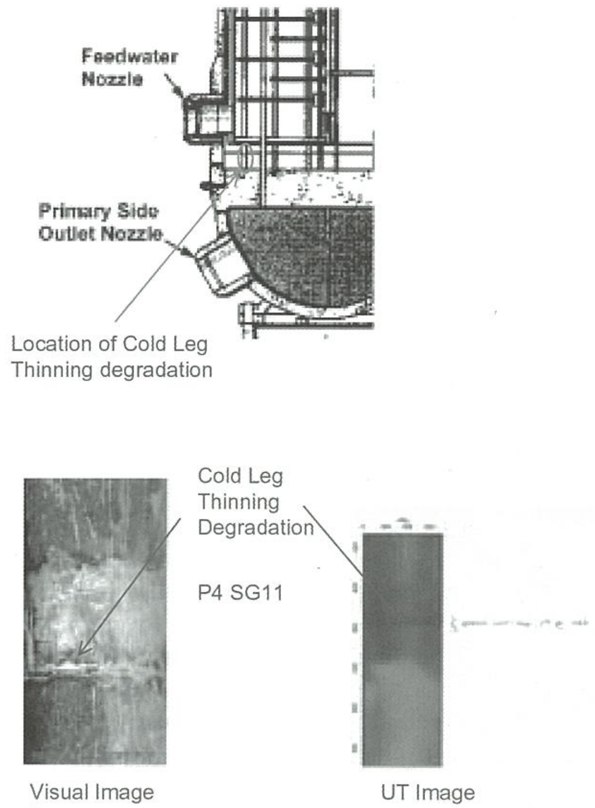


Figure 9 - Tube Cold Leg Thinning Degradation in P4

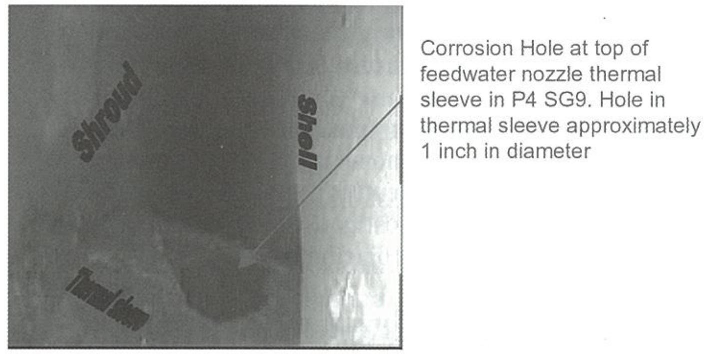


Figure 10 - Carbon Steel Corrosion of the Feedwater Nozzle Thermal Sleeve and Shroud in P4

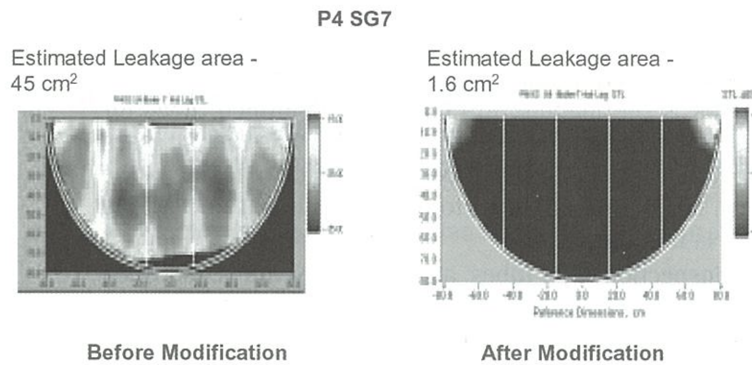


Figure 11 - P4 SG7 Primary Divider Plate Modifications to reduce leakage and improve thermal performance (Acoustic Leakage Inspection System (ALIS) measurements)

tube supports of Pickering B steam generators. The degradation is currently affecting thousands of tubes in Pickering Unit 8 (P8) but it does not appear to be active in P5 and P6 and only a small number of indications have been observed in P7. The initial metallurgical investigation of a tube removed from service pointed to erosion corrosion as the likely degradation mechanism but was unable to identify the root cause. The erosion-corrosion consists of shallow volumetric wall loss (~15% tw) and can be present in one, two or three flow holes of the broached support. The degradation at the lower edge of the support resembles the brim of a hat and hence this degradation is termed "Top Hats", see *Figure 8* for visual and ultrasonic images. Growth is presently difficult to estimate due to the limitations of the NDE techniques used to size at these shallow depths. Flaw depths are shallow at the moment but in time they could grow to a depth where the flaws will impact fitness-for-service.

To date, there is no mechanistic understanding of this degradation or the conditions or factors affecting it, therefore there are currently no available measures to mitigate this problem. In addition, because this degradation affects multiple locations in the same tube, normal corrective techniques such as tube sleeving would not be economic. Hence, for the moment, the SG LCM plan contains only careful monitoring and trending actions until root cause investigations reveal more about this degradation mechanism and its contributing causes.

Tube cold leg thinning (active at PA and PB)

A new degradation mode "Cold Leg Thinning" has been observed through in-service inspection at both Pickering A and B steam generators in the past two years. It has been observed at P5, P6, P8 and at P4. In-service inspection is currently determining the extent of degradation in the other Pickering B and Pickering A units. Cold Leg Thinning occurs as volumetric wall loss (thinning) on the OD of the tubes. Degradation is taking place around the full circumference of the tube and in some cases has a long axial extent, see *Figure 9* for visual and ultrasonic images. The degradation is at present fairly shallow (10% to 40% tw.) but there is some evidence that it is slowly growing with time, although there are NDE limitations with detection and sizing at these shallow depths and there is a general lack of repeat inspection results.

Potentially, hundreds of tubes are affected in P5. The severity (extent and depth) of degradation at P4 is not known due to difficulties with NDE. If sufficiently deep, the mode of failure could be severe and may impair the structural integrity of the affected tubes.

The causes and contributing factors of the cold leg thinning degradation are not known; there seems to be a flow component but materials and chemistry may also be contributing factors. Until the cause of degradation is known, there are no mitigating actions possible. The only SG LCM actions implemented at the moment are careful in-service monitoring, to determine extent and growth rate, and the initiation of Root Cause Investigations to determine the degradation mechanism and contributing factors.

Tube denting/deformations (active at PA)

Tube deformations have been observed in Pickering 1 - 4 steam generators at the hot leg lattice intersections. An aggressive crevice environment due to deposits and the subsequent corrosion of carbon steel supports is considered to be the cause. There are thousands of tubes affected in particular P1 and P3. The main concern with tube deformations is the inability to inspect the deformed tubes for possible degradation. A secondary concern is that stresses associated with deformed tubes may induce cracking of the tubes. Monel 400 is known to be very resistant to cracking but it is not immune.

Re-inspection of P1 tubes, after about 2 years of operation following maintenance measures (waterlancing and chemical cleaning), has shown that the number and size of deformations has not increased; deformations appear to be under control. However, visual inspection of the secondary side has shown rapid re-fouling on tube support intersections, which may lead to further tube deformation in the future if not addressed. Tube plugging is the only corrective measure available since there are no other corrective measures that would return the tubes to the original form once deformed. However, the large numbers of tubes affected means that, if all were plugged, this would consume the plugging margin available and reduce steam generator performance.

The only cost-effective SG LCM option available is to prevent further tube deformation by addressing the factors that promote carbon steel corrosion such as deposit build-up and adverse chemical environments. Removal of deposits at the support intersections by chemical cleaning is planned for all PA steam generators that have not been cleaned to date during the restart refurbishment activities or during the first planned outage after restart.

Carbon Steel Degradation of Internal Components (active at PA)

Multiple perforations and areas of carbon steel degradation have been observed by visual inspection on the thermal sleeves of the feedwater nozzles of P4 steam generators, see *Figure 10*. Carbon steel degradation has been attributed primarily to poor lay-up chemistry (PA units have been in long term lay-up since the end of 1997). The consequences of this degradation are a loss in thermal efficiency and possible debris which may result in subsequent tube failures. SG LCM actions include inspection to determine severity and extent at all four units prior to restart and repair as necessary either as part of the restart refurbishment activities or during the first planned outage after restart.

Primary Divider Plate Leakage (active at PA and PB)

The Primary Divider plate in nuclear steam generators separates the inlet plenum from the outlet plenum in the primary head. At Pickering A and B, these plates are segmented and joined together by bolts and clamped to a seat bar. The bolted design permits primary coolant to leak from the inlet to the outlet bypassing the tube bundle and thus reducing the thermal performance of the steam generators. In addition, the leakage can result in degradation of the mechanical joint which can lead to a progressive increase in leakage rate. In the P5 Spring 1999 outage the divider plates in two boilers (out of 12) were replaced with a solid floating design developed by Babcock and Wilcox Ltd. that reduced leakage and improved the performance of the quadrant. At Pickering Unit 4 all 12 steam generator divider plates were modified as part of restart boiler refurbishment activities. The divider plates at P4 were modified by installing an Inconel membrane to act as a sealing skin ("skin fix"). This was a design similar to that which had been successfully used at Bruce Unit 6 (Bruce Power). The membrane is held in place by clamping plates that were bolted to the existing divider plates. *Figure 11* compares the Acoustic Leakage Inspection System (ALIS) results before and after the "skin fix" modifications. The reduction in leakage area across the divider plate is significant and should improve the thermal performance of the steam generators once the unit is restarted. Results were similar for all P4 divider plates.

The SG LCM plans contain similar divider plate modifications for Pickering B steam generators during future planned outages and for other Pickering A steam generators as part of the restart refurbishment activities.

Tube ID Deposit Build-up (active at all stations)

Inside diameter (ID) fouling of the steam generator tubes occurs as a consequence of the dissolution of the magnetite layer in the carbon steel by the hot heat transport system (HTS) fluid and deposition of the magnetite inside the boiler tubes as the HTS fluid cools. The process is driven by the change in solubility of magnetite in D2O with temperature. ID deposits have been confirmed to be a major contributor to the rise in reactor header inlet temperatures in CANDU units and affect all OPG units. Tube ID deposits also increase dose and restrict inspection of the tubes. The SG LCM Plan actions include developing the capability to clean the ID of the tubes and to perform the clean as required.

The SG LCM plan has first tube ID clean planned for Darlington Unit 1 in 2004 and other Darlington units in subsequent years. Cost benefit analyses are being carried out to justify the application of this maintenance to Pickering B and Pickering A units.

Conclusions

The extent, severity and multiplicity of degradation modes that have been observed at OPG steam generators has made the implementation of the Steam Generator Program with corresponding Life Cycle Management Plan actions a necessity. The development, issue and adherence to set processes and procedures have enabled OPG to survive thus far and have allowed the units to continue to operate.

Nevertheless, the implementation of the SG Program and SG LCM actions has been neither easy nor straightforward. Table 1 compiles or summarizes some of the experience to date into two categories: "What Works" and "What Doesn't" and is based on actual OPG experience.

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Table I - Summary of Steam Generator Program Successes and Failures

What Works What Doesn't

- Maintaining an overall equipment health/performance perspective rather than just individual chemistry and metallurgy issues
- Knowing actual equipment condition through effective In-Service Inspection (extensive inspections, multiple NDE methods, supplemented with periodic tube removals)
- Solid, well thought out and proven rules, processes and procedures
- Maintaining rigid adherence to set rules and procedures, in particular for structural integrity issues, i.e. not relaxing rules in times of crisis (maintaining credibility),
- Consistent and transparent basis for decisions by using a structured methodology
- Keeping up with operating experience, including participating in industry sponsored initiatives
- Attention to details
- Multidisciplinary approach
- Employing a knowledgeable, experienced, conservative and very stubborn steam generator staff (with very thick skins)
- Employing a good statistician and a good structural analyst
- Effective R&D program to support the decisions you take (e.g. tube burst and leak testing program)
- Postponing key maintenance actions (e.g. deposit removal actions)
- Reactive actions or countermeasures
- Unqualified NDE (i.e. being blind!)
- Not understanding the consequences of change, in particular the long term consequences
- Unrealistic optimism
- Lack of equipment condition information (in particular original manufacturing information or early service information)
- Lack of equipment configuration management
- Not knowing root cause(s) of degradation (WANO/INPO audit finding on OPG as an area that needs improvement)
- Not knowing what to do to mitigate or stop degradation
- Poor lay-up conditions
- Placing an analyst on critical path, this leads to changing reality to match the analysis
- Short term focus

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Ben Rouben, Membership Committee Chairman

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Ben Rouben, président du comité des adhésions

Isotope Production at the McMaster Nuclear Reactor – Yesterday, Today, Tomorrow

by Elise Herzig[1]

Ed. Note: The following paper was first presented at the 23rd CNS Annual Conference held in Toronto, June 2002.

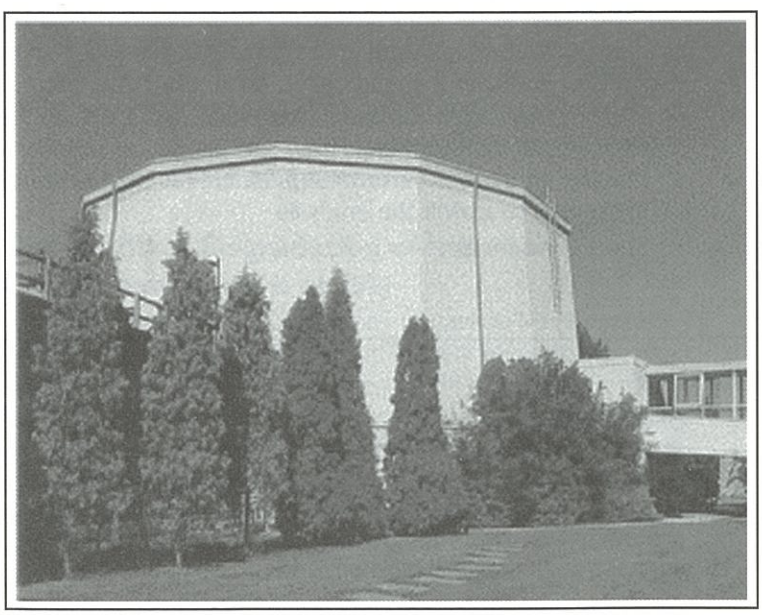
Abstract:

In June 1996, the Board of Governors of McMaster University reversed its decision to decommission the McMaster Nuclear Reactor (MNR). Critical to this decision was the new direction MNR had to take. Over the past six years, MNR has successfully repositioned itself on academic, research and commercial playing fields. One example of MNR's success is in the area of isotope production -- MNR is currently the second largest global supplier of I-125. How did MNR achieve this success? Why did it work? What is the future direction for MNR? The connection between leveraging MNR's core competencies and strategic focus will answer these questions.

Introduction:

The theme for the Twenty-Third Annual Conference of the Canadian Nuclear Society is *"40 Years of Nuclear Power in Canada: Celebrating the Past, and Looking to the Future"*. Although the McMaster Nuclear Reactor is not a power reactor, MNR and its history, both in people and research, is intertwined and strongly connected to the nuclear industry as a whole. MNR's story -- its challenges, changes and strategic decision making, parallels the experiences of the nuclear industry.

In June 1996, McMaster University had to decide to either follow through with its decision to decommission MNR or to reverse direction and keep it open. The Board of Governors chose the latter. The purpose of this paper is to reflect on the recent evolution of the MNR, and to focus on the strategic transitions that have taken place over the past six years. In looking at MNR's past, present and future, there are lessons to be shared with all members of the nuclear industry.



Background

MNR began operating in 1959 as the first university based research reactor in the British Commonwealth. MNR is a pool-type reactor, with a core of enriched uranium fuel, moderated and cooled by light water. It was designed to operate at up to 5 MW, with a maximum thermal flux of 1 x 10 14 neutrons/cm 2 per second. In compliance with international standards, MNR is in the process of converting to Low Enriched Uranium fuel while ensuring continued safe operation. MNR currently operates 16 hours per day, five days per week at a thermal power of 2 MW. MNR was a showpiece for Canada, the University and industry. As the industry grew, McMaster University and MNR attracted many academics, researchers and students who wanted to be a part.

Many of McMaster's alumni and researchers went on to play pivotal roles in the Canadian and international nuclear industry. Subsequently MNR ramped up its operations to 7 days a week, 24 hours per day; MNR's operations were well supported by Canadian research funding groups. Like most players in the industry, no one imagined that the growth cycle would end or that the positive image surrounding the nuclear industry could change.

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Included on the list of unanticipated major blows to the nuclear industry were a variety of developments: Three Mile Island, Chernobyl, cutbacks at Ontario Hydro and environmental findings on the reprocessing of reactor fuel. This combination of events had significant negative ripple effects on MNR. As labour market trends in the nuclear industry took a downturn, and as nuclear became a politically less attractive research investment for governments, so did the aura that surrounded nuclear for students and research at MNR. The decrease in students and research negatively impacted MNR's funding support. While the University had already begun to pursue alternative funding sources since the 1970's, revenue streams were not sufficient to support MNR's long term operations.

Between 1989 and 1991, MNR gradually lost all of its NSERC funding. Although MNR was actively pursuing other sources of revenue generation, none of the options were at the point where they would be viable in the short and long term.

In January 1994 an incident occurred during an MNR refuelling operation. In some ways this event reflected the complacency that is common in mature industries. The incident strained MNR's relationships with the regulator, as well as the University. The decrease in students and academic research, the increased costs associated with operating a reactor and the unlikelihood of industrial/government funding support became glaringly obvious. All of a sudden the issues surrounding MNR's financial viability became an important topic for discussion on campus.

MNR was no longer viewed as a showpiece -- it had become a liability. In addition, it was clear that with the costs associated with fuel removal, fuel purchasing and reprocessing increasing, the costs for operating reactors would rise significantly. The financial situation had been tight for a number of years, and MNR had never accrued adequate funds for facility improvements, reactor refurbishment, let alone decommissioning. In 1995, McMaster University decided to shut down MNR.

Employees and users of MNR were not informed of a final decommissioning date – all they knew was that a shutdown was imminent. Employee morale was low. However, a group on campus lobbied users to keep MNR open. Part of their strategy included a group of MNR employees who continued to work on refining and improving commercial opportunities that could help support ongoing reactor operations.

In June 1996, a business plan to continue MNR's operation was presented to McMaster University's Board of Governors. One aspect of the plan was increased production and sales of Iodine 125 (I-125). Although MNR had made small quantities of I-125 for commercial use, it had never scaled up production to meet ongoing industry needs, and had never been a significant supplier.

The University reconsidered its position, and decided to continue operating MNR. The decision was based on the following criteria:

1) the continued operation of MNR had academic merit that would meet the strategic direction of the University and support academic needs of students and researchers
2) a business plan was developed for creating a commercial business to offset some of the ongoing operating costs
3) the commercial business had the potential to contribute a revenue stream towards MNR's ultimate decommissioning

June 1996 – A new era

The decision to keep MNR open was a second chance for MNR. In order to develop and operate a viable business, MNR would have to change its approach, culture and thinking. It was clear that incremental improvements or "band-aid" solutions were not going to be enough. Moreover, MNR had to change the way it was perceived -- internally, both within MNR and on campus, and externally off campus. A new organization had to be created, even though it would continue to operate in its old environment.

To set the stage, the stakes and expectations were high. In addition to the fact that the I-125 production facility was not adequate to the challenge, and that equipment, procedures and protocols needed modifications, there were many other issues that had to be addressed. Similar to the nuclear industry, MNR faced the challenges of:

- Financial instability
- Uncertainty of future operations
- Mixed perceptions of various stakeholders
- Strained relations with the regulatory control board
- Poor staff morale
- Lack of succession planning

Many of these challenges were addressed by identifying, communicating and measuring tangible, meaningful benchmarks. These benchmarks went beyond financial goals, as success is not only measured by dollars. By having clearly identifiable goals, our internal and external stakeholders became aware of how we were measuring success. Whether informal or formal – improving communication was the number one priority.

The following additional factors were also critical to MNR being able to succeed:

- Top down and bottom up support
- Market niche – the ability to produce I-125 filled a "real" market need
- Management and staff who were empowered to do their jobs
- Right "monitoring" systems in place – monitored, evaluated and adjusted (when necessary)
- A University environment conducive to external collaborations and strategic alliances

MNR's communication strategy took place at all levels of stakeholders. The goal was to tackle the misperceptions and let everyone know what MNR was trying to achieve. This included admitting to failures and enlisting support from non-believers. This action did not convert everyone, but it did manage to reduce the flow of incorrect rumors and urban folk-tales. This communication strategy extended to dormant relationships with government and industrial contacts that had been forgotten during the early 90's. Of major importance was strengthening and rebuilding MNR's relationship with the control board which took a micro and macro approach of sharing additional information and long term objectives.

MNR also had to strengthen relationships with customers and users. The first step was addressing the issues that these groups deemed important. To create meaningful benchmarks for our stakeholders who provided MNR's revenue stream it was necessary to identify goals that were important to the users and customers who were paying for MNR's services. MNR started to think like users/customers—and this was a major change from how many University support groups have traditionally operated.

Given the importance of succeeding at the business plan, it became clear that it would be impossible for the entire organization to change at once. In fact, most of the organization did not have to change. What was essential, however, was to create a business environment within MNR that was driven by industry's needs and timetables. To do this, MNR looked at core competencies -- determined gaps within MNR's organization and started to address these deficiencies.

It was clear that MNR's greatest strength was in its staff – their ability to create, tinker and make things happen. There are pros and cons in being a small organization. In MNR's case, small meant that its talent pool of staff were forced to wear many hats and play multiple roles. As much as this is a strength, it also reflected that MNR was too thin in too many areas. Succession planning was critical. The problem was that the skills that needed to be strengthened were not ones that could easily be hired. Mentoring, transferring of skills and responsibilities had to take place.

The long-term success of the organization was dependent on the robustness of our ability to repeat tasks and achieve the necessary quality benchmarks. Even though the University had agreed to keep MNR open, many people questioned "for how long?" Internally, our team had come out of a culture where they thought they were going to be fired and therefore were unaccustomed to think "long term." It was important for the team to see the big picture and understand that their job was connected to MNR's ongoing viability. MNR needed a stronger team – therefore, in transferring of skills and delegating, staff were not concerned about pink slips – rather they were ensuring long term viability.

All organizations are bound to make mistakes. Key in the nuclear industry is the balance between creating a culture that ensures that staff will communicate errors/mistakes, while ensuring the integrity of safety and adherence to licensing requirements – and recognizing that these are not in conflict. As a result, the need for communicating clear goals and objectives became most important. Promotion of safety culture, cross training, delegation of responsibility, and improved document management systems were very important in this environment.

A key component to MNR's strategy concerning human resources was to create an environment for stars to succeed. Management's top priority was to act as linebacker for our star quarterbacks to score. What does it mean to be a linebacker for a team? Management had to accept that no job is too insignificant for a senior manager to perform to help their team. In a team environment the organization chart disappears. For example, senior management would get on the phone to make things happen – whether it meant spending hours with custom agents trying to determine why shipments were being held up or getting in a car to help deliver an equipment part for testing. The focus was always on achieving the result.

After that first year, it became clear that the June 1996 business plan was not realistic as it assumed that it would be a simple process to scale up production. However the existing knowledge and skill base of I-125 production was not adequate. Therefore, a new plan was adopted that recognized that to reinvent itself MNR needed to:

- build on its strengths
- strengthen its stakeholders' relationships
- grow at a pace that was sustainable and manageable

Tremendous energies and resources were committed to build customer confidence and change stakeholders' perceptions. Before MNR could scale up I-125 production, MNR needed to address issues relating to reliability and production capabilities, production and facility enhancements, and quality control.

As the market for I-125 brachytherapy seeds for prostate cancer grew, there was a need for expanded capacity at MNR. To achieve this MNR had to ensure reliability of supply by developing a second production facility. This second site would reposition MNR's capabilities and allow it to compete effectively in the marketplace. MNR's strategy was to develop a strategic alliance with an independent facility that could support and partner with MNR. Requirements included:

- existing license to manufacture I-125
- existing commercial radioisotope production facilities
- capacity to meet global demand
- shared values towards customers, industry and commitment to excellence
- partner's infrastructure to allow for future growth opportunities in other areas of shared interest

MNR chose to partner with Studsvik Nuclear, and a phased-in technology transfer took place. The basis for MNR's growth strategy has been to match its marketing efforts with market demand, core competencies, production capabilities, quality control and safety and regulatory requirements. The success of this approach is reflected in strengthened stakeholders' support and an expanded customer base. The synergy between MNR and Studsvik has created a win-win situation for both facilities and customers.

Many breakthrough successes were achieved through the identification of these strategic initiatives -- the development of a team with the necessary skills, resources and support, and the implementation, review and modification of key action items which encompass local and global vision. As a commercial entity, MNR moved from a mentality of "can we operate a business?" to "how to grow our business, balance our two production facilities and work towards developing additional profitable revenue streams."

The first few years were the most difficult. No one could have envisioned the hours, energy and resources required. The expression of "a journey of a thousand miles begins with one step" is very apropos, as many of our team members will attest that they feel that during those first few years they walked each step of the thousand miles.

In conjunction with building a commercial business, MNR continued to participate in fulfilling the University's academic goals. McIARS -- McMaster Institute of Applied Radiation Sciences – was founded in March 2000 to foster research, development and academic activity in a wide variety of areas using radiation science. McIARS provides a wide variety of stakeholders with the people, the facilities and the tools that will make McIARS the international research destination of choice. McIARS interdisciplinary appeal has attracted not only health and medical researchers — investigators from nuclear engineering, geology, chemistry and psychology have also joined the McIARS partnership to address questions that cross traditional boundaries. This network has created an interdisciplinary team whose synergies supports researchers, students, and partners in health care, industry, and government.

Continued success in the nuclear industry requires us to understand our core competencies and capabilities. In addition, we need to understand how our stakeholders perceive us and make decisions. This information forms the basis of developing and implementing effective strategies for success and continued growth. The role that MNR plays at McMaster continues to be very important. Our activities and products continue to be met with enthusiasm and interest from many groups. We have the protocols, people and resources to create and build on new ideas, solve problems and add value where needed. The combination of academic and commercial resources provides unique opportunities to become a major contender for research and new initiatives.

McIARS has the potential to be a world class academic and research facility, and will attract more students and academics. As the student/faculty/research base grows, McIARS will be positioned as a breeding ground of new ideas, opportunities and revenue streams. MNR's business operation will provide many of the tools and resources needed to lever these opportunities for new funding sources and strategic alternatives. The renovations to the Nuclear Research Building, the acquisition of new equipment and other infrastructure investments, combined with the marketing communications plan has created momentum.

Conclusion

On paper, change management sounds easy. In reality, it takes a team to believe and be a part of the change process. The heart of MNR's success is the combination of people, technology and resources. It is much easier to develop strategy than to change the culture of an organization. However without the "buy-in" and trust of staff, the strategies are pipe dreams. It is the people who drive, think through, develop and implement strategic initiatives as well as perform day-to-day functions. This area of business takes time, patience and an understanding of the needs and issues of the team players. MNR's team has come a long way. Successful long-term strategy requires the ability to set and monitor short term results; vigilance in monitoring and the courage to acknowledge and address mistakes.

In looking back at the past six years, MNR is proud of how far it has come as an organization, production facility and team. In July 1996, the University had a vague notion of what was required to make MNR viable. It took a lot more energy and resources than anyone imagined could be pulled together. Today, members of the MNR team look back with confidence as they know that they have turned the corner. By continuing to build on its strengths and through the strategic determination of objectives, MNR will continue to seek out opportunities which meet the longer term objectives of the University and the nuclear industry.

In 1995 when the University had originally decided to shut down MNR, it was impossible to imagine that MNR could make such a contribution to offsetting the reactor's operating costs. After all, MNR had not received NSERC funding for years, as there were no researchers championing its merit or use in their research. To quote the CFI peer review committee that approved McIARS proposal,

The proposed infrastructure is focused on upgrading and complementing the MNR and associated facilities in order to maximize their impact as a world class research and innovation centre, particularly in the areas of health and the environment. The committee is unanimous in its support of the proposal. The investment is fully justified as the experience and competencies of the existing team hold the promise of delivering major benefits in terms of training, job creation, innovation and industry development. With the proposed updated and state-of-the-art facilities, McMaster University will be able to attract outstanding scientists, younger as well as established individuals, which will help retain the best and brightest in Canadian institutions. The proposed infrastructure will no doubt provide a strong incentive to help the Institute establish partnerships with both academic and industrial institutions throughout North America, and possibly throughout the world.

The creation of McIARS will enhance and lever the talents and assets of MNR in the short and long run. Our mission is clear -- our expertise in radiation sciences has helped us to build and enhance the research excellence, capabilities and core competencies that exist both within the Institute and with our colleagues across Canada and around the world.

Our unique combination of knowledge, skills, equipment, facilities and people has positioned us to meet these challenges. MNR's evolution over the past six years, and the creation of McIARS, reflects McMaster University's commitment to becoming a proactive participant in the international nuclear industry.

Procurement and Supply of CANDU Fuels

by E.G. Bazeley[1]

***Ed. Note:** The following paper was one of three invited presentations at a special "historical" session of the 23rd CNS Annual Conference held in Toronto, June 2002.*

1. INTRODUCTION

In 1955 a decision was made to proceed with construction of a Nuclear Power Demonstration Station (NPD) near Rolfton, Ontario. This project, headed by Atomic Energy of Canada with major involvement of private industry, was the genesis for the development of nuclear electric generation in Canada. This paper reviews one aspect of the Canadian program: the evolution of fuel procurement and supply, which in itself has been a remarkable Canadian achievement.

2. EARLY DEVELOPMENTS

2.1 Fuel & Fuel Fabrication Concepts

Early in the NPD project a decision was made to change the core from a vertical pressure vessel to a horizontal vessel (calandria) with zirconium alloy (Zircaloy) pressure tubes (NPD-2). The fuel was designed and developed on the basis of uranium dioxide pellets sheathed in Zircaloy. The NPD fuel bundles were initially configured as 7 element bundles for the outer reactor channels and 19 element bundles for the inner channels. The bundles were relatively small. Approximately 50 cm long and 8 cm in diameter to be compatible with the inner diameter of the NPD pressure tubes and the criteria for on-power fueling of the reactor.

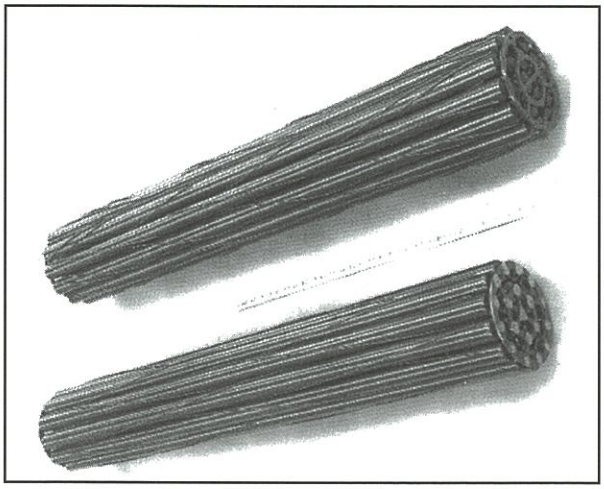

Figure 1: 19 Element Fuel Bundles

As illustrated in Figure 1, the initial bundles were based on using spot welded Zircaloy wire wrap on the elements as element spacers and bearing surfaces. Because of concerns about crevice corrosion and the possibility of some of the wire being detached during appendages. Similarly the end cap to sheath closure welds were originally made using the Tungsten Inert Gas (TIG) process. After considerable development work a highly reliable Resistance Butt welding process was adopted.

The 19 element bundle design was also selected for the 200 MW (e) Douglas Point reactor, construction of which was committed in 1959. With the commitment of the NPD project, Atomic Energy of Canada (AECL) invited and encouraged the participation of private industry. In 1955 General Electric Canada (GEC) formed its Civilian Atomic Power Department and undertook the detailed design of the

1 Ed Bazeley is "semi-retired" from Ontario Hydro and now is president of E.G. Bazeley & Associates.

NPD reactor. Westinghouse Canada Ltd. (WCL) formed its Nuclear Energy Division in 1956 and undertook the design of experimental loops for AECL's NRU research reactor.

The AECL initiatives included nuclear fuel; the first being a request for proposals for the establishment of a plant for fabrication of uranium metal fuel for AECLs NRX and NRU research reactors. This resulted in the establishment in 1957 of a plant at Port Hope, Ontario by American Machine & Foundry Co. under the name AMF Atomics Canada Ltd.

Shortly thereafter initiatives were launched for the development of processes for manufacturing uranium oxide fuel for NPD, Douglas Point and subsequent CANDU reactors. Eldorado Nuclear undertook the development of processes for production of uranium dioxide (UO2) powder suitable for making high-density ceramic fuel pellets. GEC and AMF Atomics Canada carried out AECL funded development work on pellet and bundle fabrication methods.

2.2 Procurement & Supply Developments

The reactor development work of the late 1950s and early 1960s spurred the initial evolution of the domestic fuel manufacturing industry. During that period, since most of the fuel work was developmental, most of the orders were placed on the basis of a call for proposals with negotiation. Natural uranium (as uranium oxide in concentrates) was readily available from domestic sources in Ontario and Saskatchewan due to the needs of the US defense program. Eldorado Nuclear had established a solvent extraction plant for purification (refining) of mine concentrates and a small (500 MgU per year) conversion plant to produce uranium dioxide (UO2) powder from ammonium diuranate (ADU) solution.

In this early period GEC was the principal supplier of fuel bundle manufacturing service.

Their initial manufacturing plant in Peterborough, Ontario was able to produce the first charge of fuel for NPD-2, some 1188 bundles for loading in early 1962. At the outset the initial plant relied mostly on manual fabrication processes. However, subsequent extensive development was to change that situation markedly. In 1964 the AMF Atomics operation was purchased by Westinghouse Canada Inc., which then sought to prepare the plant for a broader role in the growing fuel manufacturing market.

3. MAJOR REACTOR PROGRAMS

3.1 Fuel & Fuel Fabrication Concepts

The next phase of Ontario Hydro's major reactor program was the construction of the Pickering A station with 4 - 500MW(e) CANDU reactors, which were brought into service in the 1971 to 1973 period.

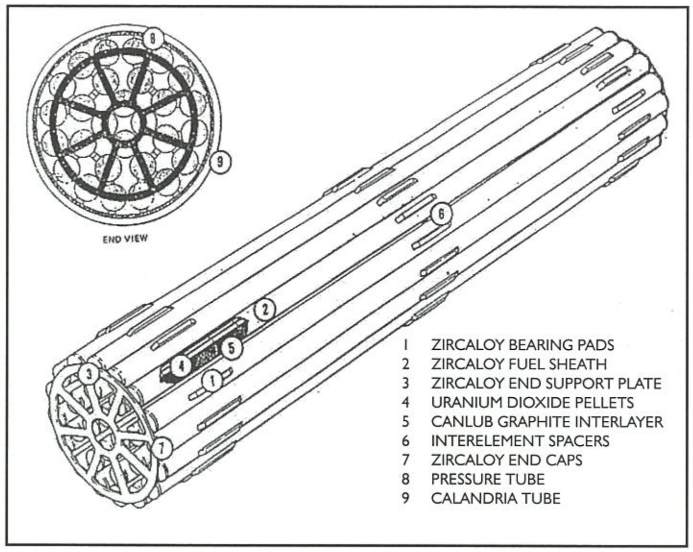

Figure 2: 28 Element Pickering Fuel Bundle

Before the first two Pickering units were completed the station design was modified to allow for 8 - 500 MW (e) reactors, the last 4 being brought into service in the 1983 to 1986 period. The fuel bundles for Pickering used essentially the same elements as the Douglas Point reactor but in a 28 element, 10 cm diameter cluster to match with the larger diameter pressure tubes (10.4 cm vs. 8.25 cm for Douglas Point). Figure 2 shows a 28 element Pickering fuel bundle:

In late 1968 Ontario Hydro committed the construction of another major Phase, the Bruce A station consisting of 4 -750 MW(e) reactors which were brought into service in the 1977 to 1979 period (upgraded to 848 MW(e)). This was followed by the Bruce B station with 4 – 860 MW(e) units coming into service in the 1984 to 1987 period. The last major project was the Darlington station with 4 – 881 MW(e) units, which came into service in the 1990 to 1993 period.

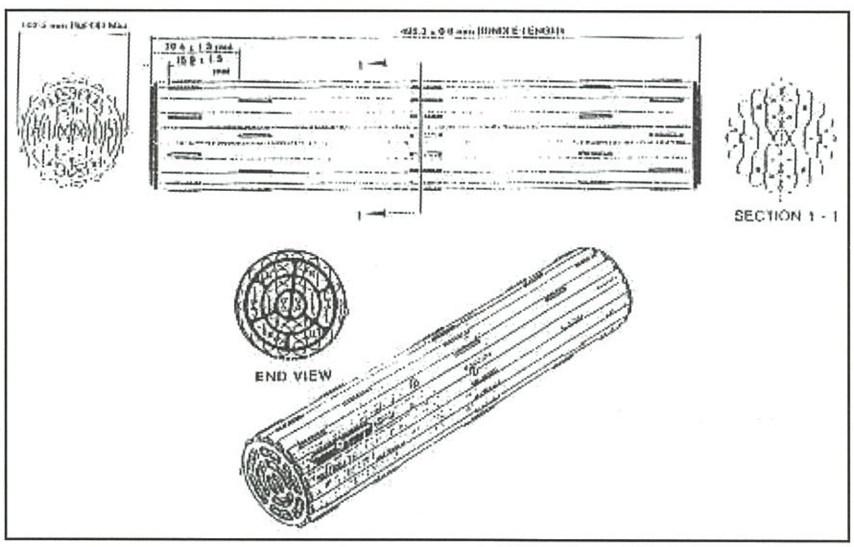

Figure 3: 37 Element Fuel Bundle

The fuel bundles for the Bruce reactors and for the Darlington reactors followed the same concept as the

Pickering fuel bundles with the same length and outer diameter but with a 37 element cluster of 0.5 in (13 mm) diameter elements (vs. 0.6 in for Pickering). The 28 and 37 element fuel bundles became, and remain today, the standard fuels for the Ontario Hydro (now Ontario Power Generation) reactors. The 37 element bundle was also adopted by A.E.C.L for 600 MW(e) reactors. Figure 3 shows a 37 element fuel bundle:

Key characteristics of these fuels may be summarized as follows:

- The fuel is natural uranium and therefore does not require enrichment and preparatory conversion to UF6. The uranium concentrate is refined and converted directly to U02 powder, which must be of a consistency suitable for the production of high-density pellets. Green pellets are compacted, then sintered at high temperature (1750 0C) in a hydrogen atmosphere to form stable ceramic pellets that can be centerless ground to close tolerance.
- The pellets are sheathed in thin (0.4mm) walled Zircaloy-4 tubes with resistance welded end caps. Under operating conditions the sheath tubes collapse onto the pellets.
- The elements are resistance welded to structural Zircaloy-4 end plates and are separated by beryllium brazed spacer pads. The outer circle of elements have beryllium brazed Zircaloy-4 bearing pads to support the bundles in the horizontal coolant tubes.
- With natural uranium the fuel burn-up levels are relatively low, being of the order of 200 MWh / kgU (300 MWd/MTU).

Key fuel bundle manufacturing considerations are as follows:

- The basis for CANDU fuel procurement, at least for the major customer Ontario Hydro (and now for OPG) places a design responsibility on the supplier. Working with the customer's specifications and outline drawings, the supplier must complete the detailed fuel design and have it approved by the purchaser. The supplier completes its own shop drawings and includes its own innovative features. The suppliers, therefore, need to have substantive in-house design capability.
- A fuel manufacturer should be fully equipped to produce high quality, thin walled Zircaloy tubing. Buying it from other sources may not be satisfactory as some or all of it might have to come from competitors. The annual quantity of tubing needed was projected to be about 1.5 million metres when all 20 of Hydro's reactors were in operation. The most common approach has been to purchase tube reduced extrusions from sources in Europe and the USA and then reduce these using large and progressively smaller pilgering machines.
- A fundamental aspect of CANDU fuel manufacturing is the production of high-density, crack free U02 pellets. The U02 starting material needs to be pre-tested to ensure its performance. The process steps involve powder conditioning, compaction to green pellets, high temperature sintering, then grinding to achieve a smooth finish and dimensional accuracy. When all 20 of Hydro's reactors were in service the needed volume of pellets would be in the order of 70 million/yr.
- Another particularly critical process is welding the fuel element end caps to seal the elements after loading the pellets. The practice is to use a butt type resistance weld under very precise and closely controlled conditions. The welding machines are mainly designed by the fuel manufacturers themselves. They are sophisticated, automatic machines, which must be capable of making large numbers of flawless welds in the thin walled sheath tubes. Each manufacturer must design the weld preparation to suit their own equipment. The fuel bundles for operation of Hydro's 20 reactors would entail some 20,000 of these closure welds per day.
- The quality standards for CANDU fuel are stringent because of the serious effects of fuel failures in a reactor core. The reference quality standard for CANDU fuel manufacturing was developed by the Canadian Standards Association (CSA) and designated as Can-3 – Z 299.2. This standard specifies the minimum requirements for a manufacturer's Quality Assurance Program. It outlines the elements that must be planned, controlled and documented (more than 20 such elements) to ensure that the product meets the specified requirements. In 1997 Ontario Hydro and its fuel suppliers adopted the higher level standard Z 299.1, which has some additional requirements.

In regards to product quality, an essential point to recognize is that CANDU fuel is a volume manufactured product. Therefore, the emphasis for Quality Control must be aimed at on-line process control so that potential and actual defects and errors can be detected and dealt with quickly. Also, all materials must be traceable from their origin to the finished parts.

3.2 Procurement & Supply Development

As the construction of Canadian nuclear stations progressed both Westinghouse and General Electric expanded and perfected their fuel bundle manufacturing capability. Their investments increased capacity and introduced greater levels of automation and process control. By the late 1970s their combined capacity had reached at least 1600 MTU per year and it would later climb to some 2400 MTU per year. Both companies initially obtained Zircaloy tubing from their parent companies in the USA but later established their own Canadian tubing operations.

A third supplier, Combustion Engineering Ltd., decided to enter the bundle manufacturing market in the 1970's. They established a small (300 MTU / yr) plant in Moncton, New Brunswick which could produce small volumes of accept-able quality fuel by 1978. However, given the technological advances already made by the established companies, it was very difficult for C.E. to break into the market and they decided to withdraw in 1983.

In 1988, Westinghouse agreed to sell their Port Hope and Cobourg fuel operations to Zircatec Precision Industries (ZPI), a new company formed by Contor Holdings Ltd. of Toronto. In the years following the entry of ZPI, that company and GEC both expanded the capacity of their plants to about 1200 MTU per year.

In parallel with the expanding fuel industry, Cameco Corporation (formerly Eldorado Nuclear) expanded their uranium refining and conversion capability. A new solvent extraction refinery was established at Blind River and new facilities were constructed at their Port Hope site for conversion to U02 powder for CANDU fuel and for conversion to UF6 to be used as feed for enrichment plants serving international LWR programs.

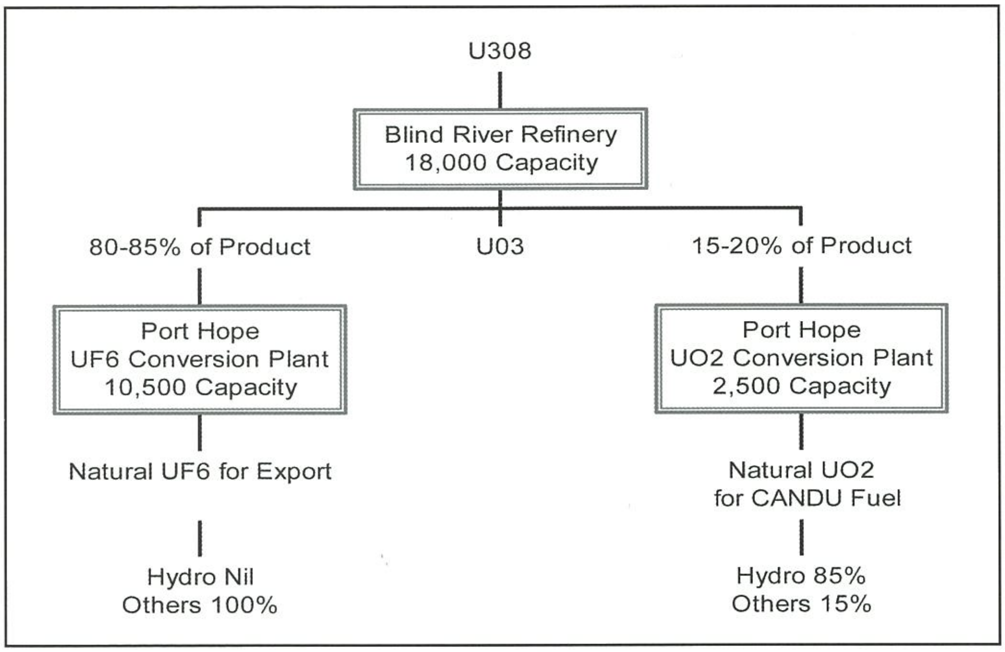

Figure 4: Cameco Refining & Conversion Facilities, MgU/Year

Figure 4 (below) is a diagram outlining the Cameco processing facilities with approximate production capacities and product streams:

Ontario Hydro, the major purchaser of CANDU nuclear fuel, based its procurement program on purchasing its own uranium and uranium refining/conversion services. This enabled the utility to have strategic control over these items and to take advantage of the economy of bulk purchases.

As well, Ontario Hydro adopted fuel bundle purchasing strategies and practices that would encourage the continuance of a strong, competitive supply industry with at least two capable supply companies. The usual approach was to seek tenders for a significant portion of their estimated future requirements over a term of about three years. The tender request for these base orders would normally list a number of alternative annual quantities so that split ordering could be considered. For Ontario Hydro's supplemental fuel bundle requirements, tenders were usually sought on an individual basis for each year's needs.

For Hydro's uranium refining and conversion needs there was (and still is) only one fully capable source: Cameco's Blind River and Port Hope plants. The mutually agreed procurement approach in this case was the development, by negotiation, of long term contracts, which recognized the mutual dependence of each company on the other and the need for reliability and economy to support the Canadian nuclear program. Contracts of this kind can deal with the questions of volume flexibility and volume price effects by establishing volume price tables during the negotiations. Perhaps the most challenging aspect of this supply situation was, and still is, the need for the supplier to meet stringent specifications on the U02 powder and also to pass the fuel bundle manufacturer's pre-tests on samples.

As the Canadian nuclear reactor programs moved forward, coincidentally, dramatic changes unfolded in relation to uranium procurement and supply. During the 1950s uranium mining in the northern areas of Ontario and Saskatchewan expanded rapidly in response to the needs of the cold war defense programs in the USA. By 1959 Canadian production reached a level of some 32 million lbs U308 (12,000 MTU). However, shortly thereafter the defense purchasing was curtailed and most of the supply contracts were not renewed. As a result, the number of mines shrunk from 25 to 3 by the mid 1960s and uranium could be purchased for under US$ 8.00 per lb U308 (US$ 20 / kgu).

By 1973, with increasing world development of nuclear generation and a general concern about energy resources, procurement activity accelerated and prices soared. Figure 5 shows approximate uranium spot prices from 1971 to 2001.

To ensure access to a sufficient Canadian uranium reserves to protect the growing Ontario nuclear program and to comply with Canadian Government regulations (which required utilities to contract for their needs for 15 years) Ontario Hydro entered into major uranium supply contracts with Elliot Lake producers. The contracts, with Denison Mines and Rio Algom, could provide more than 6 million lbs U08 (2,400 MTU) per year with pricing related to the cost of production. The contracts both required advance payments (for mine development), which were paid back each year as the material was delivered. They also had termination provisions, which could be used to protect Ontario Hydro if the material became uneconomical in relation to world uranium prices.

As the following chart in Figure 5 shows, world uranium prices did begin to fall significantly in the early 1980s and that trend continued into the 1990s. The main reasons for this were:

- The high world prices for uranium in the 1975 to 1981 period spurred uranium exploration which resulted in major finds of economical to mine deposits, particularly in Australia and western Canada.
- Material from Former Soviet Union (FSU) countries began to become available in the world market.
- As concerns about scarcity of supply diminished, both industry and governments looked to reducing strategic inventories.
- The end of the Cold War and the Strategic Arms Limitation Treaties (SALT) created the need to deal with the large amounts of highly enriched uranium (HEU) prepared for, or removed from, the scrapped missiles. The obvious solution is to use the large amounts of uranium feed andseparative work units of enrichment (SWUs) contained in this material for low enriched (LEU) fuel for LWR reactors.

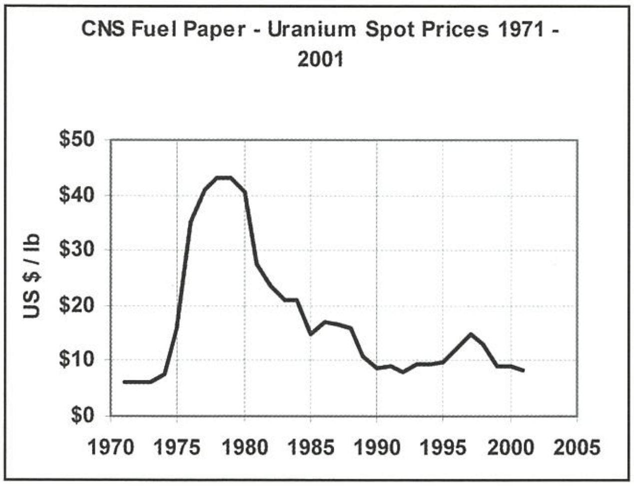

Figure 5

Consider that 1 kg of 96% enriched HEU requires 187 kg of natural uranium feed and 245 SWUs, whereas 1 kg of 4% enriched uranium for LWR fuel requires 7.4 kg of natural U feed and 6.5 SWUs for enrichment. (at 0.2 enrichment tails).

An agreement between Russia and the USA provides for 30 MTU per year of Russian HEU to be blended down to LWR fuel level. This produces an amount of LWR fuel that would normally require about 24 million lbs of U308 feed.

Given the changed conditions in the uranium market, Ontario Hydro took action in 1991 to terminate the Elliot Lake contracts. Deliveries from Denison Mines ended in 1992 and those from Rio Algom were completed in 1996. The utility then sought and obtained new medium term contracts with low cost producers in Saskatchewan and Australia. These covered a major portion of the projected needs but left room for further advantageous purchases as opportunities might arise.

By the mid 1990s the Ontario Hydro nuclear fuel procurement program and the contributing supply programs could be characterized as mature, economical and reliable. Furthermore, fuel quality was maintained at a satisfactory level due to the supplier's Quality Assurance programs and the high level of co-operation between the suppliers and the utility.

4. FURTHER EVOLUTION

4.1 Current Situation

The trend in the USA and in Canada to move away from regulated, government owned utilities means that running costs and in particular fuelling costs are no longer a `pass through ' item in electricity rates. It also means that electricity generators are already facing competition or are preparing to do so. This increases the need to minimize and control fuel costs. It has also resulted in more aggressive fuel procurement practices and the use of some new and more imaginative purchasing techniques such as:

- Off-Market deals for uranium, which do not use conventional tendering but may facilitate some very good deals that can be put together quickly.
- Internet auctioning and bidding on specified quantities of uranium and/or conversion.
- A tendency for purchasers to want shorter-term contracts with greater volume flexibility and delivery timing options.

There continues to be abundant supplies of low cost uranium concentrate for the reasons mentioned earlier. However, there will likely be some movement upward from the present US $10 / lb range due mainly to the fact that primary world production is currently covering only about 60 % of total demand and the consumption of inventories will soon begin to diminish. Also, the use of surplus military material cannot continue to fill the gap indefinitely.

Sources for conversion and fuel bundle manufacturing are presently adequate for the domestic nuclear program as mentioned earlier. The prolonged shutdown of 8 of Ontario Power Generation's reactors (a reduction of some 40 % of their nuclear capacity) continues to be a difficulty for the bundle manufacturing shops because of their volume sensitive nature.

The long-term lease of the Bruce A and B generating stations to Bruce Power Inc. means that there are now two competing nuclear generation entities in Ontario. This appears to have brought in an era of strategic alliances and changes to the traditional procurement and supply patterns for nuclear fuel in Ontario. The participation of Cameco in the Bruce Power generation business is in itself a strategic initiative since it brings fuel materials and services supply expertise into a venture where control of fueling costs is a key success factor.

The announced contract whereby GEC will provide all of OPG's needs of 28 element Pickering fuel and 37 element Bruce and Darlington fuel is a significant change from the traditional bidding processes used in the past. It may be assumed that this arrangement was a negotiated deal wherein the parties recognized the mutual dependence that each has upon the other. The contract whereby ZPI will provide all of Bruce Powers 37 element fuel needs for the duration of the Bruce lease creates a similar strategic alliance.

These arrangements would appear to have the advantage of having a supplier/ purchaser team that can work together to ensure that the high quality and cost effectiveness that is needed to compete is achieved. On the other hand, these are single source deals and as such they do not provide the level of protection against generic defects, labour relations problems etc that can be achieved with multiple sources. An increase in the strategic inventory level would help to reduce this concern.

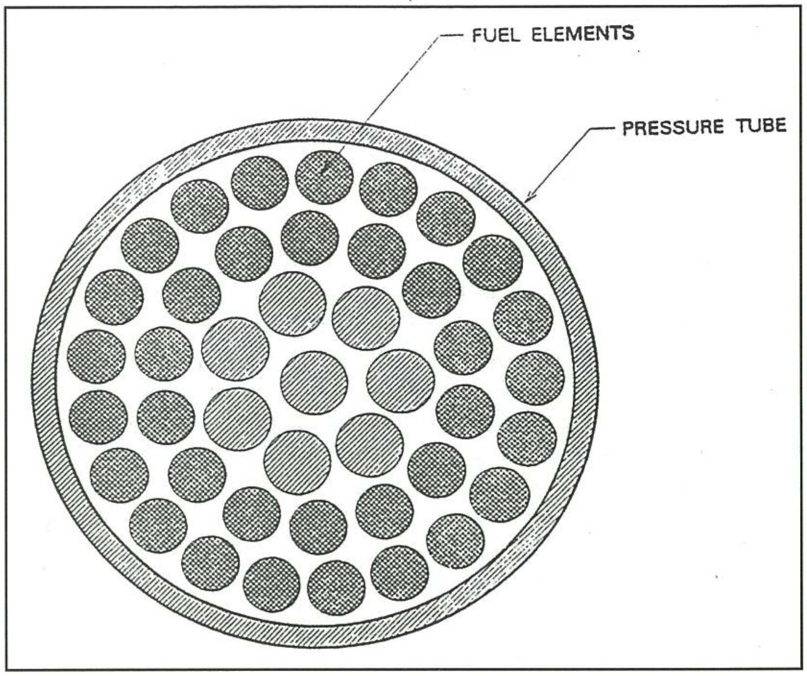

Figure 6: 43 Element CANFLEX Fuel Bundle

4.2 Future Developments

For the foreseeable future in Canada and the USA it seems likely that the trend towards utility consolidations, the emergence of merchant generators and the formation of strategic alliances will continue. It is equally likely that relentless efforts to increase capacity factors and reduce running costs will be continued. For the existing and future CANDU reactors there are a number of significant options or changes that could be advantageous in certain circumstances. Some of these are:

Slight Enrichment (SEU)

Slight enrichment of the uranium in CANDU fuel can significantly increase the attainable burn-up level and thereby reduce the rate of fuel throughput. Studies at Ontario Hydro in 1989 indicated that using the existing 37 element Bruce fuel bundles with enrichment to 0.9 wt % U235 would approximately double the burn-up (195-390 MWh/ kg U). This would reduce the fuel bundle requirements by about 50% and the uranium requirements by about 25%. It would yield good savings even with an increase in the unit cost of fuel because of an extra conversion step and the enrichment cost.

Canflex Fuel Bundle

The CANFLEX fuel bundle is a design developed by A.E.C.L. It is a 43 element bundle assembly that offers improved operating and safety margins as compared to the standard 37 element bundle. The CANFLEX bundle consists of two element sizes; small diameter elements in the outer and intermediate rings and larger diameter elements in the inner and centre rings. The basic overall dimensions of the CANFLEX bundle were designed to be the same as those of the 37 element bundle. This bundle is a sound option to consider in a number of circumstances. It is particularly applicable in conjunction with a change to Slight Enrichment or to the use of Mixed Oxide (MOX) fuel. .Figure 6 illustrates the CANFLEX fuel bundle geometry:

The CANFLEX bundle, with a greater number of elements in two diameters, and a greater number of appendages, is more complicated from a manufacturing standpoint. However, the Canadian fuel manufacturing firms, with their automated assembly processes are well suited to handle the task.

Next Generation CANDU

The NG CANDU reactor concept being advanced by A.E.C.L. is a most promising Venture. It uses the CANFLEX fuel bundle with enrichment, which should result in very good performance. The manufacture of the low enriched fuel bundles should not present any serious problems. The unit cost of the bundles would increase significantly due to the added cost of enrichment and a second conversion. However, the increase in burn-up level would more than compensate for that.

Mixed Oxide Fuel

Studies carried out on the use of MOX fuel in CANDU reactors were directed towards the dispositioning of excess weapons grade plutonium. The studies looked at the use of the 37 element fuel bundle or the CANFLEX bundle and confirmed the suitability of CANDU reactors for the dispositioning task. The MOX option remains as an important peace initiative in which Canadian CANDU reactors could play a vital role.

5. CONCLUSIONS

The CANDU fuel story marks an outstanding achievement in that fuel economy and reliability has been central to the success of CANDU reactors. Much of the achievement is due to the high level of co-operation between A.E.C.L and the industrial participants in the early development years and onward. The steadfastness of the fuel manufacturing firms and the application of responsible, cooperative procurement policies and practices has contributed to the ongoing success.

The prospects for further advances in fuel design concepts, fuel manufacturing and procurement practices are good but challenging. Close cooperation between designers, users and the supply industry is essential, particularly in times of change.

The maintenance of quality standards, quality assurance and skilled surveillance must continue to be a high priority.

A further consideration is the need to ensure that sufficient technical expertise and skills are maintained to ensure current performance and to carry out new programs and development initiatives.

6. ACKNOWLEDGMENTS

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Advanced Construction Methods in ACR®

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Abstract

The ACR – Advanced CANDU® Reactor, developed by Atomic Energy of Canada Limited (AECL), is designed with constructability considerations as a major requirement during all project phases from the concept design stage to the detail design stage. This necessitated a much more comprehensive approach in including constructability considerations in the design to ensure that the construction duration is met. For the ACR-700, a project schedule of 48 months has been developed for the nth replicated unit with a 36 month construction period duration from First Concrete to Fuel Load.

An overall construction strategy that builds on the success of the construction methods that are proven in the construction of the Qinshan CANDU 6 project has been developed for the ACR. The overall construction strategy comprises the "Open Top" construction technique using a Very Heavy Lift crane, parallel construction activities, with extensive modularization and prefabrication.

In addition, significant applications of up to date construction technology will be implemented, e.g. large volume concrete pours, prefabricated rebar, use of climbing forms, composite structures, prefabricated permanent formwork, automatic welding, and utilization of the latest electronic technology tools such as 3D CADDs modelling yields a very high quality, clash free product to allow construction to be completed 'right the first time' and eliminates rework. Integration of 3D CADDs models and scheduling tools such as Primavera has allowed development of actual construction sequences and an iterative approach to schedule verification and improvement.

Modularization and prefabrication are major features of the ACR design in order to achieve the project schedule. For the reactor building approximately 80% of the volume will be installed as modules or prefabricated assembles. This ensures critical path activities are achieved.

This paper examines the advanced construction methods implemented in the design in order to achieve the construction schedule. Typical ACR modules will be presented and their features discussed.

Keywords: AECL, ACR, Advanced CANDU Reactor, advanced construction, module, constructability, schedule, optimized, nuclear.

1. Background

For the new build nuclear option to be competitive, short construction schedule is essential. Implementing the construction method considerations right from the conceptual design stage of the project makes achieving the short schedule possible. Atomic Energy of Canada Limited (AECL) has been very successful in implementing new construction methods at the Qinshan (Phase III) twin unit CANDU 6 plant in China. This project involved implementing new construction methods with a minimum number of design changes, to an existing design that has already been built conventionally many times.

The Qinshan site is very compact with the sea on three sides. This was a major challenge for implementing a new construction method using the open top technique, utilizing a very heavy lift crane and finding adequate laydown area for modules. In spite of these challenges, the new construction techniques were successfully implemented in Qinshan CANDU Project. The success achieved at Qinshan further increases confidence in these new construction techniques.

To achieve a shorter schedule, the construction method/strategy must be defined very early in the concept phase of the design, as it has a major impact on the construction schedule. This strategy is then included in the design requirements and considered in the plant layout as the design of the new product progresses. The individual designers focus on this strategy from the earliest stages of layout to completion of the detail design. In addition, innovative solutions are applied to the prefabrication assemblies/modules being designed to ensure the schedule can be met. For ACR, the construction method considerations are implemented as a requirement during the conceptual design phase, resulting in fully integrated layout with construction methodology and reduced schedule.

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1 Atomic Energy of Canada Ltd., Mississauga, Ontario

2. Overall Plant Layout & Construction

In the ACR-700 Overall Plant Layout, the Reactor Building (RB) is surrounded by the Reactor Auxiliary Building (RAB), a multilevel concrete structure which includes the spent fuel bay and associated fuel handling facilities/systems, electrical and safety related process equipment/systems. The Turbine Building (TB) is located perpendicular to the Reactor Auxiliary Building with the Crane Hall positioned between these two structures. The Control Building contains the main control room and associated control and electrical equipment. See Appendix A Figure 1 for a simplified layout of the 2 unit ACR-700.

The layout of the Reactor Building has been developed taking into consideration the construction method to ensure full integration of the plant layout with the proposed method of construction. When the layout of a system is being developed, a particular area/volume is identified within the Reactor Building in which to fit the particular systems(s). Thus, planning for module construction becomes an integral part of the layout and design process. Both the RAB and the TB will be constructed in parallel with the RB and will also make use of prefabrication to ensure the 36 month schedule is achieved.

3. Project Schedule

The traditional project milestones considered in the project schedule are:

- Contract Effective Date (CED) refers to the date the contract is in place and the first orders can be issued.
- First Concrete (FC) refers to the start of construction of the Reactor Building base slab. This requires construction license (1st Concrete.).
- Fuel Load (FL) refers to the activity of loading the first fuel charge.
- In-Service (I/S) refers to the in-service date for the unit.

Appendix C illustrates the project schedule evolution for CANDU 6 plants and the proposed schedule for the ACR-700 plant. For Qinshan CANDU Unit 1, in China, the construction period, FC to FL is 47 months with a total project duration of 72 months. For a repeat CANDU 6 plant, this construction period (FC to FL) can be further reduced to 42 months. Building on the Qinshan experience and further utilization of advanced construction methods, the ACR 1st unit construction period is 40 months, which can be further reduced to 36 months for the nth unit.

4. Construction Strategy for ACR-700

Historically, most planning effort for construction methods has been applied to the RB, which had most of the major critical paths. However, the shorter the schedule becomes, the more the other sections of the plant become schedule critical. With the reduced schedule all sections of the plant have their own critical paths, which must be addressed.

However, the RB with its internals is still the most complex structure. Therefore the construction method for the RB is highlighted in this paper.

The construction strategy for the ACR-700 is based on:

- Open Top Construction
- Parallel Construction
- Prefabrication/Modularization
- Use of Up-to-Date Construction Technologies

As stated earlier, this strategy has been successfully implemented in Qinshan units 1 and 2 as shown in Appendix B. For ACR, this strategy will be further extended to achieve a shorter schedule.

5. Application of Construction Strategy

This section discusses the application of two of the major elements of the construction strategy, prefabrication/modularization and up-to-date construction technologies.

Prefabrication/Modularization

The more activities that can be performed in parallel rather than series improves the overall schedule. Modularization and prefabrication are ideal techniques for doing work in parallel. Multiple modules can be fabricated in a shop while the civil work is progressing ready to receive the modules.

The major reason to use prefabrication/modularization techniques is to shorten the schedule but there are also many other advantages that contribute indirectly to the project success:

- significantly reduces direct construction labour costs
- reduces indirect construction cost
- reduces worker population on site
- improves access to work areas
- allows work to be completed away from the final construction area
- improves safety during construction
- easier to achieve required quality
- reduces conventional shoring and scaffolding requirements
- shortens durations of critical activities
- removes activities off the critical path

In order to implement the prefabrication/modularization approach, a method is required to place these prefabrications at all areas within the plant. Recent developments in very large mobile cranes have made this technique very practical.

Very Heavy Lift (VHL) cranes have made it feasible to leave the top off the containment structure and install the internals through the "open top" construction method (Appendix A Figure 2 and 3). The Reactor Assembly will be the heaviest lift made with the VHL crane and as such it will define the size of crane required. There are cranes from several manufacturers available that are capable of making this heavy lift.

As a result of the "open top" method, temporary construction openings in the RB wall are eliminated which is a major cost saving and also leads to an improvement in containment quality.

The VHL crane can also be used in other areas of the plant for installing large equipment/modules, including the Reactor Auxiliary Building and Turbine Building.

Reactor Assembly

The reactor assembly concept developed for ACR-700 includes a calandria and integrated shield tank supported on four feet, stabilized by four horizontal seismic pads to the reactor vault wall. The reactor assembly also includes fuel channels, lower feeders and reactivity mechanism deck being assembled prior to installation (Appendix A Figure 4). From a construction point of view this is a good arrangement as it simplifies the civil program by not requiring complex work to be done embedding the Calandria Shield Tank Assembly (CSTA) in the civil structure, as is required for the conventional CANDU 6 design.

This major prefabrication moves a very substantial amount of work offsite as a prefabrication assembly that can be installed open top using the VHL crane. This reactor assembly will have a long manufacturing duration and therefore it is advantageous to install it as late as possible. Traditionally, there is no other equipment above the reactivity deck, so late installation only impacts the vault close up and therefore all other work in the RB can progress (Appendix A Figure 5).

Module Development

Modularization for ACR-700 is achieved through a multidisciplinary team. A dedicated team is responsible for coordinating the design and producing design deliverables for the modules. During initial layout of the building, a multidisciplinary team is involved to select the best locations for systems and equipment and to decide on optimum locations and configurations for modules. For each module, a module project engineer is responsible for the layout of the piping systems and to optimize and coordinate input from all disciplines for the design. Since modular design is compact to optimize space utilization and constructability, operation and maintenance (O&M) review is critically important. O&M input and review by a specialist has become a part of the module design work process. The design of a module is also being reviewed twice by a multidisciplinary team, once at the preliminary design stage and a second time at the final design. 3D CADD tool is used to generate drawings for module fabrication. Multidiscipline drawings are put together into a fabrication package using AECL in-house electronic tool 'TRAK', based on AECL's experience on Qinshan construction packages.

Some of the other typical modules being developed for ACR-700 are described below:

Moderator Module:

The Moderator Module is a structural steel module supported on a concrete slab (see Appendix A Figure 6). It is located on the base slab of the reactor building (see Appendix A Figure 7) with the top of the module steel base flush with the top of base slab fill pour. The module includes a pump, heat exchanger, coolers and associated auxiliary systems. Two Moderator System modules are required, one as shown and the other being its mirror image.

This system installation, traditionally a critical path activity, is removed from the Reactor Building for earlier fabrication in parallel with the civil construction. The area is congested and ideal for prefabrication as a module.

ECC Valve Station Module:

The ECC Valve Station Module (see Appendix A Figure 8), is a structural steel module supported from concrete silo walls. The module is located at elevation 116.4m (see Appendix A Figure 9). This module includes ECC valve station, piping and the room floor (grating/structural steel).

Moderator Purification System Module:

The Moderator Purification System Module includes equipment and piping located in shielded concrete enclosures/compartments (see Appendix A Figure 10). Permanent formwork acts as the module structural frame and after installation through the open top, the walls and floors are filled with concrete to provide the required shielding. These shielding walls and floors are essentially concrete/steel composite structures. This module is located at elevation 108.00m (see Appendix A Figure 11).

HT Pressurizing Pump Module:

The Heat Transport Pressurizing Pump Module (see Appendix A Figure 12) includes 2 pumps, piping, associated equipment and structural frame located at elevation 116.4m (see Appendix A Figure 13). The prefabricated permanent formwork would be lowered into place onto wall brackets to provide the room floor. After anchoring to the walls, the HT pressurizing pump module would be lowered into position, anchored and the floor filled with concrete.

Feeder Headers with Associated Pipe Whip Assembly:

The Feeder Header/Pipe Whip Assembly (see Appendix A Figure 14) is a module that has traditionally been used for CANDUs. It includes the headers, upper feeders, feeder cabinet frame and pipe whip restraint steel. The piping is very congested and ideal for prefabrication in the shop.

Up-to-Date Construction Technologies

Application of the following up-to-date construction technologies to the ACR-700 will help to achieve a shortened construction schedule:

- Large Volume Pours - With the development of low-heat concretes, large volume pours are practical and have major benefits. Pours up to 6 m deep will be utilized and vertical bulkheads minimized.
- Prefabricated Rebar - To meet a tight schedule, large quantities of prefabricated rebar assemblies will be required. Rebar installation by individual bar placement is very time-consuming and produces long durations for critical path

activities. For such areas as the basemat, containment walls and internal structural walls, rebar assemblies will be designed for prefabrication wherever possible.

- Use of Climbing Forms - For improved schedule and precision of poured concrete, climbing forms will be used for both the reactor building containment and internal structure walls.
- Use of Composite Structures - The composite structures being considered are essentially large steel fabricated box sections that are later filled with concrete for compressive strength, shielding and seismic qualification. These structures, when combined into modules have the advantage of eliminating formwork and rebar.
- Use of Prefabricated Permanent Formwork - It is often necessary to install equipment in an area and then install the floor above it. This is required because it is physically impossible to install and remove conventional shoring and this also impedes work in the room if it is filled with shoring. In these areas it is often more practical to design a bridging system (usually steel containing prefabricated rebar) that will span over the top of the room and will act as the formwork.
- Use of Automatic Welding - Much greater use of automatic welding will lead to reduced welding durations, improved weld quality and reduced weld repair. This will be applied to all piping systems but particularly large size heavy wall piping, and also for the steel containment liner welding.

3D CADD (Computer Aided Design and Drafting) is being used to develop construction sequences to match the schedule through links with Primavera, the scheduling software. In addition, 3D CADDs provides a high quality output with minimal field interferences due to clash checking capabilities.

6. CONCLUSION

The ACR-700 is designed using the latest construction methods to achieve a 36 month construction period for the nth replicated unit. A strategy has been developed based on the proven successful implementation in the Qinshan project. This strategy is further extended for implementation in the ACR project to achieve the shorter schedule and reduce project costs and improve quality.

Appendix A – Figures

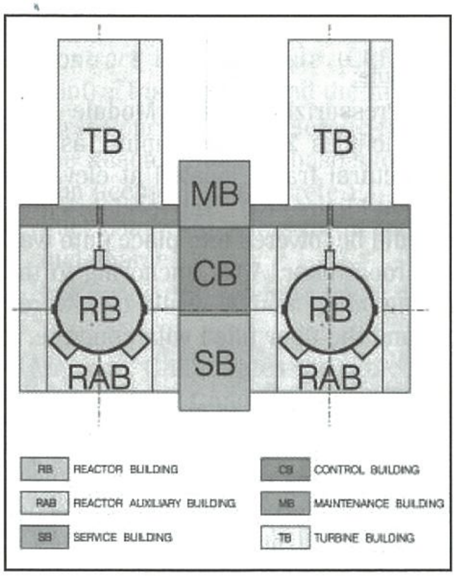


Figure 1 – Simplified 2 Unit ACR-700 Layout

Figure 2 – Lowering of a Dousing System Module Through "Open Top at Qinshan

Figure 3 – Positioning of a Dousing System Module at Qinshan

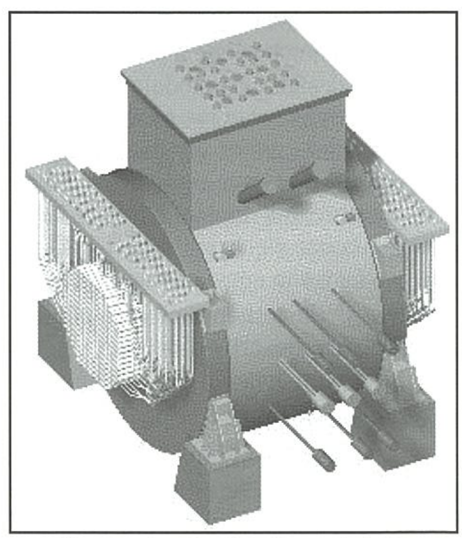


Figure 4 – Prefabricated ACR Reactor Assembly

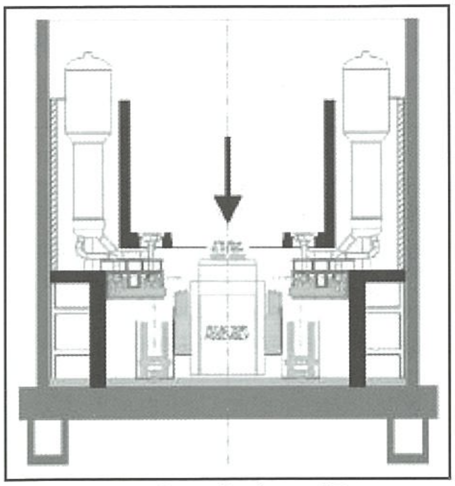


Figure 5 – Installation of Reactor Assembly into Reactor Building

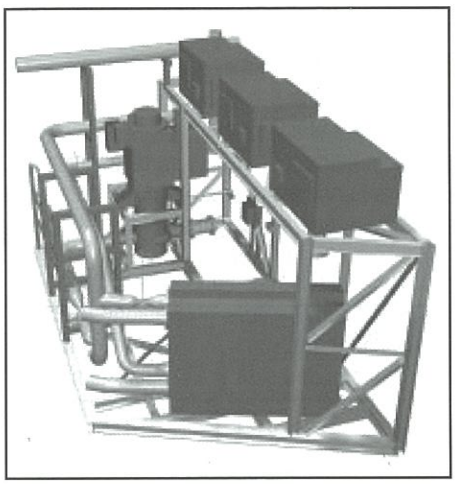


Figure 6 – Moderator Module

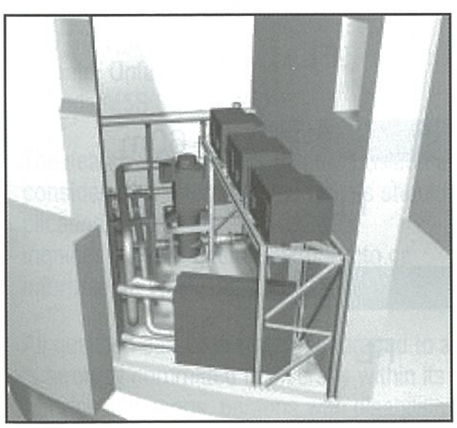


Figure 7 – Moderator Module Installed in the Reactor Building

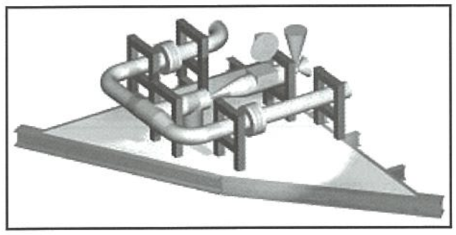


Figure 8 – ECC Valve Station Module

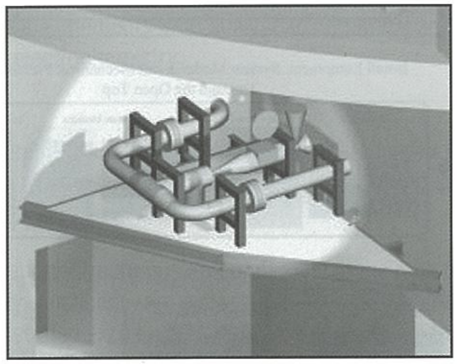


Figure 9 – ECC Valve Station Module Installed in the Reactor Building

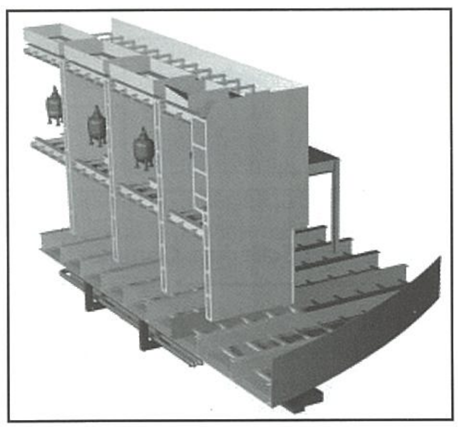


Figure 10 – Moderator Purification System Module

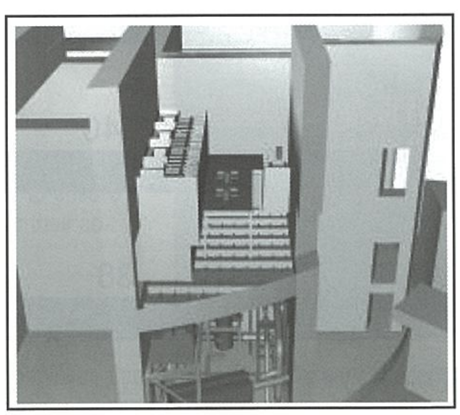


Figure 11 – Moderator Purification System Module Installed in the Reactor Building

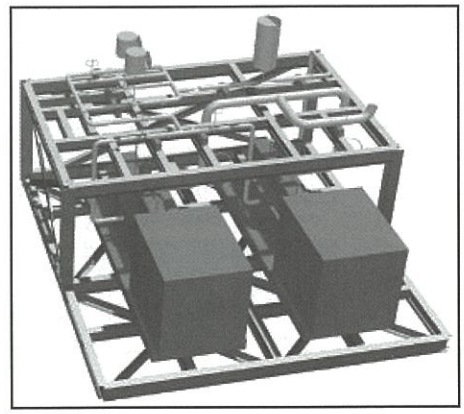


Figure 12 – HT Pressurizing Pump Module Installed in the Reactor Building

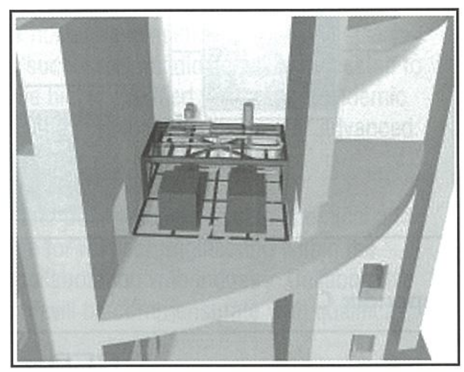


Figure 13 – HT Pressurizing Pump Module Installed in the Reactor Building

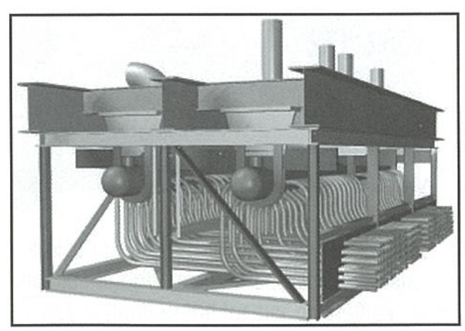
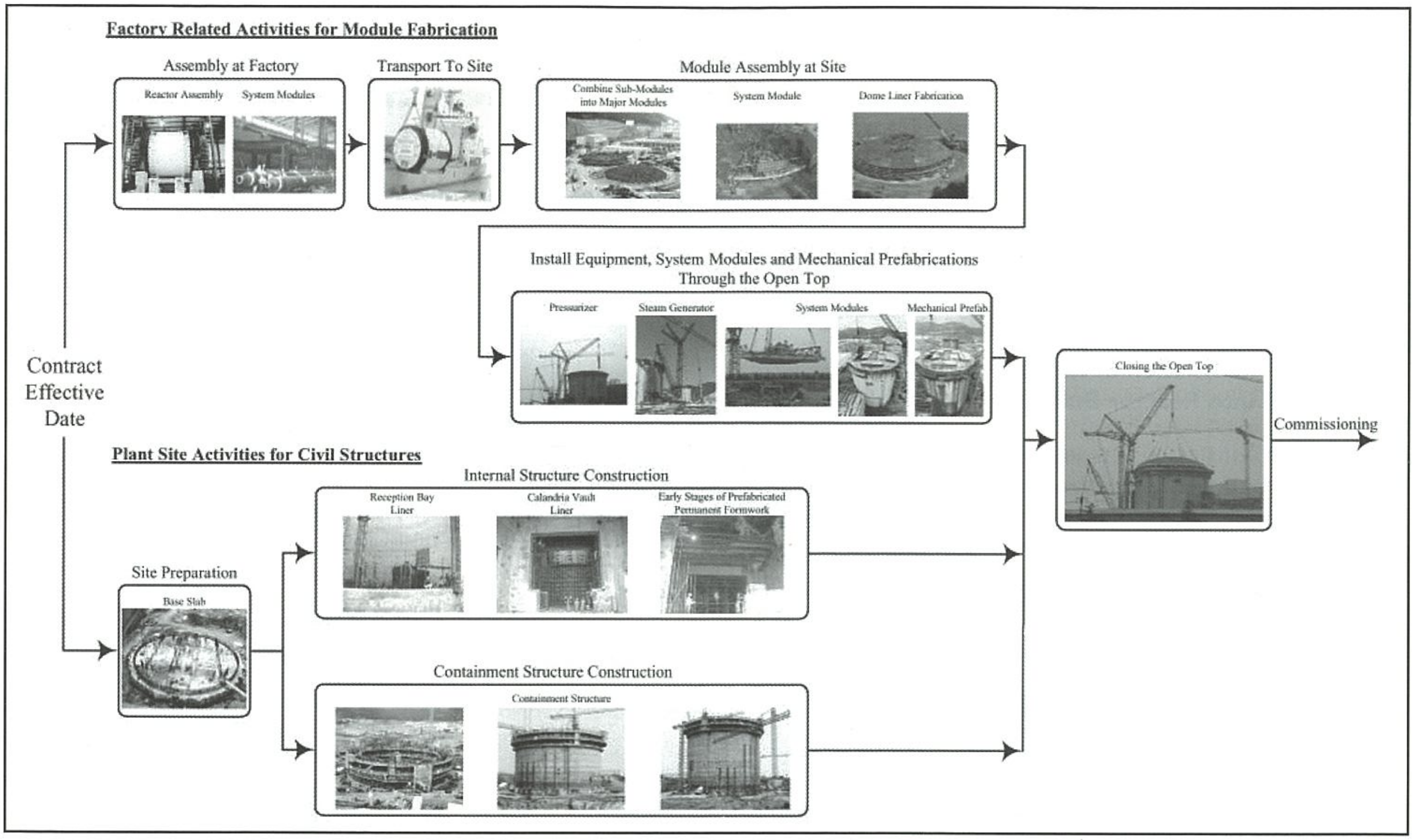


Figure 14 – Feeder Header/Pipe Whip Assembly

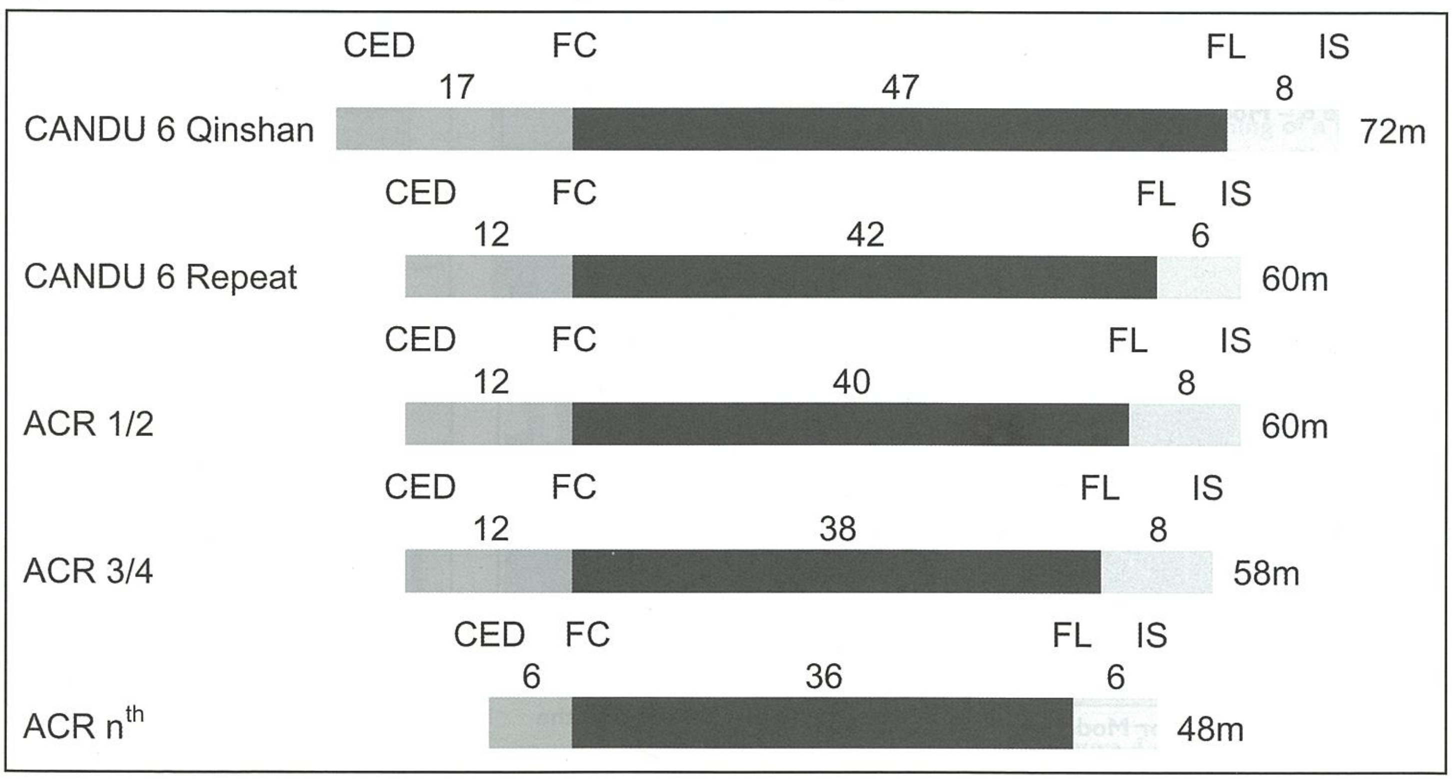
Appendix B

Qinshan CANDU 6 Construction Method Paralleling of Factory And Plant Site Activities For The Reactor Building



Appendix C

Simplified Schedule Comparison



NUCLEAR CHEMICAL ENGINEERING AND APPLIED CHEMISTRY
UNIVERSITY OF TORONTO

The Department of Chemical Engineering and Applied Chemistry invites applications for two positions in Nuclear Chemical Engineering. These positions are part of the major initiative to re-establish nuclear engineering research and training of highly qualified personnel in Ontario through the University Network of Excellence in Nuclear Engineering (UNENE). These positions will be closely linked and will be important components of the strategic plan of the Department. In the context of these appointments, research fields of strategic interest to the Department are:

- surface/interface analytical techniques, reactions, and mass transfer
- mathematical modeling of solution or surface chemistry with analytical, numerical and/or informatics expertise
- high temperature aqueous chemistry and electrochemistry
- free radical / radiation chemistry.

Industrial support through UNENE has created the opportunity to establish, with matching funding from the Natural Sciences and Engineering Research Council (NSERC), these two positions. Candidates will be expected to assist in preparation of the proposal to NSERC. These positions are contingent upon successful application for funding.

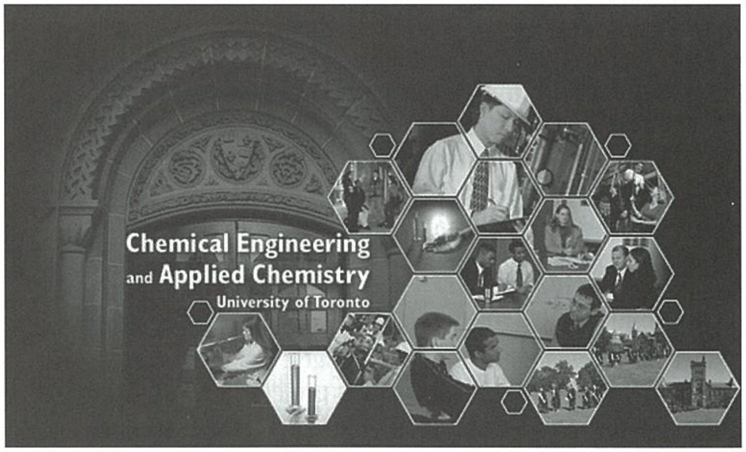
The NSERC Industrial Research Chair is to be a tenure-stream position preferably at the rank of Assistant Professor, although candidates appropriate to higher rank are also invited to apply. Applicants are expected to have a PhD or equivalent, a strong background in chemical or nuclear engineering or physical sciences, demonstrated excellence in research and excellent teaching skills. The successful candidate will be expected to initiate and lead an independent research program of international caliber.

The NSERC Executive Industrial Research Chair is to be a five-year-term contract position at the rank of Associate Professor or Professor. Applicants are expected to have a PhD or equivalent experience, a strong background in chemical or nuclear engineering or physical sciences, demonstrated excellence in research or advanced engineering and excellent teaching skills. The successful candidate will be expected to participate in research of international caliber. The successful applicant for the Executive Chair will be highly qualified with a non-academic research or advanced engineering background, from industry or other sectors, with extensive experience in managing research or advanced engineering technology at a senior level.

For each of these positions the successful candidate will be expected to teach at the undergraduate and post-graduate level in chemical and nuclear engineering and/or applied chemistry. Both chairs will be expected to contribute to the Centre for Nuclear Engineering within the Faculty of Applied Science and Engineering and to UNENE and to promote nuclear-related research collaboration with industry. Collaborative and inter-disciplinary research and collegial interaction will be important elements in success. Salary will be commensurate with qualifications and experience.

Applicants should send a curriculum vitae and a statement concerning research and teaching interests (three to five pages), and should arrange to have sent directly three letters of reference to:

Professor Douglas Reeve,
Frank Dottori Professor of Pulp and Paper Engineering,
Chair,
Department of Chemical Engineering and Applied Chemistry,
University of Toronto,
200 College St.,
Toronto, Ontario,
Canada M5S 3E5.



The search will continue until the position is filled. To ensure consideration, interested individuals should deliver their application before January 10, 2003.
Inquiries: chair@chem-eng.utoronto.ca
Information: www.chem-eng.utoronto.ca

All qualified candidates are encouraged to apply; however, Canadians and permanent residents will be given priority. The University of Toronto is strongly committed to diversity within its community and especially welcomes applications from visible minority group members, women, Aboriginal persons, persons with disabilities, members of sexual minority groups, and others who may contribute to the further diversification of ideas.

GENERAL news

AECL applies to decommission Whiteshell

Atomic Energy of Canada Limited has formally applied to the Canadian Nuclear Safety Commission for a licence to decommission its Whiteshell Laboratories in Manitoba.

Following the CNSC two-day hearing process AECL first appeared at the Commission's September 12, 2002 session. The second day was held November 14.

AECL is requesting a six-year licence for what it calls "Phase 1" of the overall decommissioning of the laboratories during which most of the actual decommissioning of building and facilities will be conducted. That is to be followed by phase 2: a 10 year "storage with surveillance" period, and subsequently by phase 3, a 40 year further "storage and surveillance " and eventual "final decommissioning". CNSC staff has supported the initial six-year licence.

Among facilities to be decommissioned in phase 1 are the Van der Graff accelerator and Neutron generator, both of which are to be "fully decommissioned". The reactor, WR-1, will remain in a "storage with surveillance" state during phase 1. There are about 250 personnel on the WRL site and that number is expected to remain for at least a few years as the decommissioning proceeds.

In response to questions at the Nov. 14 hearing, Dr. Paul Fehrenbach, head of AECL's laboratories, stated that phase 1 would cost about $50 million, which has been set aside in a special fund.

Osborne comments on Pickering A delays

In a speech given in mid October, Ron Osborne, CEO of Ontario Power Generation, provided some views, from his perspective, on the continuing delays in the re-starting of the four nuclear units of OPG's Pickering A station.

Following are some excerpts from his talk.

"Turning now to Pickering A, we expect to begin commissioning the major components of the refurbished Unit 4 during the first quarter of 2003. The in-service date will depend on the success of commissioning, and our plan is to have Unit 4 back in service by the end of the second quarter. The total cost for Unit 4, which includes a lot of work on common operating systems for all four units, is approximately $1.2 billion.

As to why the schedule for return of the first unit has been delayed compared to our initial estimates, there are a number of major reasons.

The first is that we were overly optimistic right from the start on the schedule and the budget. We significantly underestimated the complexity of this project.

Pickering A is a first-generation multi-unit CANDU station, designed and built in the 1960s and early 1970s, that is being brought up to today's standards. We plan to operate it for at least 10 years after we return the station to service.

The complexity of the job has become clearer through each step in the rebuilding process for Unit 4. The restart of Unit 4 involves the completion of almost 35,000 tasks, including the replacement or updating of many major components, and the maintenance of everything that is not being replaced. Integration of all these tasks has been a major challenge. The project also involves the coordination of 1,300 building trade workers, 700 engineering and project support staff, and 1,000 OPG employees.

The number of component modifications and upgrades involved make this project the largest nuclear restart project ever undertaken in the nuclear power industry. Both the revised cost and the time involved to rebuild Pickering A are in line with other major North American nuclear restart initiatives. For example, Tennessee Valley Authority announced in the spring that they plan to return to service their Browns Ferry Unit 1 reactor to service. TVA estimates it will cost about Cdn$2.5 billion to bring back the unit – which will have just over half the capacity of Pickering A -and that it will take five years to return the reactor to service.

Another contributing factor to the length of time needed to restart Unit 4 was the time needed for a formal environmental assessment.

In 1998 we had conducted an environmental review of the Pickering A and B stations, with community involvement. It was our view at the time we proposed the Pickering A restart that this review adequately assessed the environmental impacts of the project and identified the appropriate mitigating actions. It became apparent after discussion with the regulators that a formal environmental assessment under the auspices of the Canadian Environmental Assessment Act would be required. The environmental assessment process lasted almost 20 months – from July of 1999 to February 2001. We did not feel it was prudent or proper to begin the major rebuilding work until after we received the go-ahead by the regulator.

A third factor, which in hindsight contributed to schedule delays, was our decision to contract out key aspects such as project management and design engineering.

We began planning for the restart project while we were still heavily involved in the nuclear improvement programs at Darlington, Bruce B and Pickering B. We did not have the staff capability to do both projects at the same time, and we decided that the improvement and safe operation of Darlington, Bruce B and Pickering B would take precedence. Consequently, we moved OPG nuclear staff to these operating stations and contracted out project management and design engineering for the Pickering A restart to other companies. Having a combination of contractors and OPG sharing management of the project did not work. We have since taken over full responsibility for managing the project, with contractors assisting us.

Design engineering has particularly taken a great deal of time to get right. A combination of unrealistic deadlines, conflicting demands and poor overall management on our part led to the delivery of engineering products that were often incomplete and not well integrated.

In summary, the complexity of the restart project, the length of the environmental assessment process, and our decision to contract out project management and design engineering are some of the major factors that have contributed to the schedule delays and cost increases for the Pickering A project. Despite the delays and additional costs, it is worth proceeding with this project."

NEI head gives W. B. Lewis lecture

Joe Colvin, president and CEO of the Nuclear Energy Institute, gave the W.B. Lewis Memorial Lecture in Ottawa, OCTOBER 23, 2002, on the subject, *Nuclear Energy: Fulfilling the Promise.*

Reporting on the record safety and efficiency of the US nuclear power industry in recent years he said that the [US] nuclear energy industry had gained enormous credibility among policymakers and the public by virtue of improved performance – in efficiency and even more importantly in safety. He added that "nuclear energy's affordability and reliability alone would justify a role for the technology in the new century. But an even more important reason is the mounting concern over the environment – air quality, and in particular global warming." In the United States, nuclear energy accounts for three-fourths of all emission-free electricity generation.

"Our most recent public opinion survey shows that two-thirds of the American people favor nuclear energy as part of our electricity mix, and more than three quarters believe that nuclear energy should play a role in meeting future U.S. energy needs", Colvin stated.

Looking to the future, Colvin discussed NEI's *Vision 2020* strategic plan for industry growth unveiled last year. *Vision 2020* calls for 50,000 megawatts of new nuclear capacity in the United States by 2020, and another 10,000 megawatts of expansion from existing capacity. Colvin explained that the industry has a number of initiatives in place to support *Vision 2020*, including demonstrating the Nuclear Regulatory Commission's new early site permitting program for new reactors and a program to attract young professionals to the industry.

The W.B.Lewis lectures, which honour the memory of Dr. Wilfrid Bennett Lewis who was scientific head of AECL's Chalk River Laboratories for over two decades and considered the architect of the CANDU nuclear power system, are sponsored primarily by Atomic Energy of Canada Limited, with the co-sponsorship of Carleton University, University of Ottawa, and the Canadian Nuclear Society.

Nuclear Waste Management Organization established

On November 15, 2002 the *Nuclear Fuel Waste Act* was put into force. The Act was first introduced into the House of Commons on April 25, 2001 and received Royal Assent on June 13, 2002. It requires the utilities with nuclear power plants to create a Waste Management Organization.

In anticipation of the Act coming into force the utilities formed the Nuclear Waste Management Organization and appointed Elizabeth Dowdeswell as President of the new organization. Richard Dicerni, executive vice-president of Ontario Power Generation is Chair of the Board of Directors of NWMO.

Elizabeth Dowdeswell most recently has been Visiting Professor in Global Health, Genomics and Ethics at the University of Toronto. From 1993 to 1998 she served as Executive Director of the United Nations Environment Program. Prior to that she was Assistant Deputy Minister at Environment Canada. She has a B.Sc. from the University of Saskatchewan an M.Sc. from Utah State University and several honorary degrees.

The Act requires the NWMO to submit, within three years, its proposed approaches for the management of used nuclear fuel. The approach to be followed will be chosen by the Governor in Council (Cabinet) and then it will be the responsibility of the NWMO to implement the approach. The NWMO must also establish an Advisory Committee to comment publicly on its work.

Qinshan unit connected to grid

Qinshan CANDU unit 1 was synchronized to the Chinese grid on Monday, November 18th, at 17:30 hours, marking the first "CANDU" electricity generated in China. When connected the reactor power was at 25% and the turbine generator was loaded to 8% power or 58MWe.

Commissioning continued with the TG loaded first to 20 % power and then to 25% power over the following 24 hours. A formal ceremony to celebrate grid connection took place November 19th. AECL's vice-president and project director, Ken Petrunik, noted that this achievement is a further result of the successful co-operation and partnership of the Qinshan Team---TQNPC, Chinese Construction Contractors, AECL, CNPM and Hitachi/Bechtel and thanked all who had been involved over the years to achieve this success.

Shown at a ceremony on the occasion of the first fuel loading of Qinshan III unit 1 on August 2, 2002, are (L to R): Xu Yuming, vice-chair China Atomic Energy Authority, Ken Petrunik, AECL vice-president and Qinshan project director, and Li Dangfan, president China National Nuclear Company.)

CNSC gains two new Commissioners

Two new members of the Canadian Nuclear Safety Commission were appointed in June 2002.

Dr. James A. Dosman is a Professor in the Department of Medicine at the University of Saskatchewan in Saskatoon and a Fellow of the royal College of Physicians and Surgeons of Canada. He is also an associate member of the Western College of Veterinary Medicine. His fields of expertise include respiratory diseases, occupational diseases and agricultural medicine. He received the Distinguished Scientist Award from the Medical Research Council in 1998 and has been awarded a number of fellowships and scholarships in medical research.

Dr. J. Moya J. McDill is a professor in the Department of Mechanical and Aerospace Engineering at Carleton University in Ottawa and Associate Chair, Undergraduate. She has also held the position of Associate chair to the Natural Science and Engineering Research Council / Nortel Joint chair for women in Science and Engineering. Her primary research has been in the development of special elements and techniques for analyzing weld and stress in many manufacturing processes.

CRUISE conference explores energy policy

The Carleton Research Unit on Innovation, Science and the Environment of Carleton University held a two-day conference in Ottawa, October 17, 18, 2002 on the topic of *Canadian Energy Policy in the Sustainable Development Era.*

Conference coordinator Bruce Doern set the stage with his opening paper on *Seven Key Policy Issues and Challenges: Canadian Energy Policy in the Sustainable Development Era.* He proposed that the seven key policy issues are:

- Is Canada planning a low carbon economy
- The Kyoto Protocol and Energy National Unity
- Bush alternative to Kyoto
- Re-emergence of energy security
- Northern pipelines, aboriginal peoples and sustainable northern development
- Federal science and technology policies and energy innovation
- Further institutionalization of sustainable development.

His paper gave an outline of each of these topics as a prelude to the 11 papers that followed and the several panel discussions.

Nuclear energy was hardly mentioned. The most reference to nuclear was in Robert Morrison's paper on *Energy Policy and Sustainable Development* and, despite his background as former head of the Nuclear Energy office at Natural Resources Canada he was not very optimistic about the role that nuclear would play.

It is intended that the papers, modified as a result of the discussion at the conference, will be published in a forthcoming book.

For information contact Prof. Doern at < bruce_doern@carleton.ca >

Five new appointments to AECL Board

Over the past six months the federal government has appointed five new members to the Board of Directors of Atomic Energy of Canada Limited. They are:

Terance McCann, a lawyer and former Mayor of Pembroke, Ontario, who has been involved in a number of tribunals and committees such as Ontario Municipal Board, Human Rights Commission and Ontario Labour Relations Board.

Barbara Anthony Trenholm, accountant and professor at University of New Brunswick in Fredericton. She is a Fellow of the Institute of Chartered Accountants.

Douglas W. Thompson, a partner in the law firm of Hatter, Thompson and Shumka, of Victoria, B.C.. He has been on the boards of B.C. Hydro and Power Authority, Power Exchange Corporation, and the University of Victoria.

Stella M.Thompson, (no relative) a principal of the firm Governance West Inc., a management consulting firm in Calgary, Alberta. She is also on the boards of Deloitte & Touche, and Talisman Energy.

Peter P. Dhillon, president of Richberry Farms Ltd in Richmond B.B., who is a member of the 2010 Whistler - Vancouver Olympic Bid Committee.

Large attendance at ANS Winter meeting

Possibly reflecting the renewed optimism in the USA about a "nuclear renaissance" the winter Meeting of the American Nuclear society in Washington D.C., November 17 -21, 2002, drew the largest attendance of recent years, about 1,200.

The structure of the meeting was similar to recent ANS meetings with a plenary session the first morning, two more special plenary sessions late Tuesday and early Thursday, and up to 15 parallel "technical" session the remainder of the time.

Richard Meserve, chairman of the US Nuclear Regulatory Commission, was the lead-off speaker of the opening plenary session. After noting that the Commission is reviewing five designs for early design approval he listed three major challenges: ageing of NRC staff; licensing of the Yucca Mountain spent fuel disposal facility; and the need for more international cooperation. While the USA may be on the threshold of a nuclear renaissance there is a need for continuing vigilance by all involved, he stressed.

In response to a question Meserve revealed a good awareness of AECL's ACR design and noted discussions with the regulatory agencies in Canada and the UK.

Other speakers at the opening plenary were: Sean O'Keefe, administrator of NASA, who spoke on the need for nuclear power for long space voyages: Paul Robinson, of Sandia National Laboratory, whose subject was "Global Nuclear Future - Meeting Future Energy and Security Needs"; Dr. Evgeny Pavlovich Veliikhov, of the Kurchatov Institute of Russia, who looked at the future of fusion and advanced fission reactors; and John Sununu, former governor of New Hampshire. Sununu, who has a doctorate in nuclear engineering, quipped that when he was asked why he went into politics he replied "to save us from lawyers". His major message was a call for engineers and scientists to get engaged in the public debate about nuclear energy.

David Torgerson, senior vice-president at AECL, spoke in a special plenary session on "Economics of New Nuclear Power" on the morning of the last day and AECL Technologies, AECL's subsidiary in the USA, had a prominent booth in the exhibition accompanying the meeting.

The venue was shifted slightly to the upscale Omni Shoreham Hotel where the "special" room rate was $180 (US). Combined with a registration fee of $600 (US) and extra charges for special luncheons and dinners the cost was a marked contrast to CNS events.

A view of the AECL Technologies booth at the exhibition of the American Nuclear Society winter meeting in Washington, D.C., November 2002.

OPG transfers safety group to NNC

In September, Ontario Power Generation finalized an agreement with NNC Holdings Ltd. of the UK to transfer approximately 150 of its nuclear safety analysis staff to a new company, Nuclear Safety Solutions Limited, a wholly-owned Canadian subsidiary of NNC Holdings.

Commenting on the agreement, OPG president Ron Osborne said, "we were one of the few nuclear operators to rely on in-house service for nuclear safety analysis ands concluded that it would be advantageous to combine forces with an established nuclear technology company".

At this time the staff are still located at OPG's head office building, 700 University Avenue in Toronto.

NNC Canada Limited, another subsidiary of NNC Holdings, was already a major supplier of safety and engineering services to Bruce Power, which is majority owned by British Energy.

Commissioning resumes on MAPLE 1

At the end of October 2002 the Canadian Nuclear Safety Commission authorized Atomic Energy of Canada Limited to resume low-power commissioning of the MAPLE 1 reactor. MAPLE 1 is the first of a pair of small reactors being built at the Chalk River Laboratories by AECL for MDS Nordion. They will be dedicated to the production of medical radioisotopes for processing and distribution by MDS Nordion.

AECL interrupted the commissioning of the MAPLE 1 reactor in July 2000 after problems were encountered during testing with the operation of the reactor's shut-off rods. An extensive program was launched in July 2000 to identify the cause of the problems and to confirm the as-built quality of the MAPLE 1 reactor, the MAPLE 2 reactor and the New Processing Facility.

In December 2001, AECL applied to the Commission for approval to resume low-power commissioning of the MAPLE 1 reactor, to load fuel in the MAPLE 2 reactor and to start active commissioning of the New Processing Facility. The Commission ruled that a number of prerequisites identified by the CNSC staff had to be completed before the CNSC staff would authorize resumption of nuclear commissioning. These have now been met.

Preston leaves OPG

At the end of September 2002 Gene Preston left Ontario Power Generation where he had been Senior Vice President and Chief Nuclear Officer for the past three years. He had come to the then Ontario Hydro in 1997 with the group of American advisers brought in to review the state of the nuclear operations of the utility. When Carl Andonini returned to the USA Preston took over the senior nuclear office.

In a note to OPG employees Preston wrote, "I have decided, for personal reasons, to retire from Ontario Power Generation." "I have enjoyed my association during these past six years and I wish only the best for it and for each of you in the future." "I look forward to the day when OPG has 12 nuclear units in service."

OPG CEO Rob Osborne referred to Preston's desire to return to the United States and then announced a major change in the organization. Nuclear operations is now integrated with the other operating sections of the company and now reports through the Chief Operating Officer, Graham Brown. Bill Robinson has been assigned full responsibility for all of the Pickering station.

Obituary

Dr. Kenneth F. Hare, died September 3, 2002, in Oakville, Ontario, at the age of 83.

Kenneth Hare was an internationally recognized environmental scientist and meteorologist. He was born in Wales in 1919 and educated at the University of London and Université de Montréal.

His academic career included appointments as Dean of Arts and Science at McGill University; Master of Birkbeck College at the University of London; President of the University of British Columbia; Director of the Institute for Environmental at the University of Toronto; Provost of Trinity College at the University of Toronto and Chancellor of Trent University.

Although not a participant in the Canadian nuclear program in the strictest sense, Dr. Hare was very involved in several studies and inquiries. In the late 1970s he was a co-author of a study on the management of spent nuclear fuel. That report resulted in the large program conducted primarily at the Whiteshell Laboratories of Atomic Energy of Canada Limited and the associated Underground Research Laboratory in Manitoba. In the nuclear community he is probably best remembered as chairman of the Ontario Nuclear Safety Review of the 1980s. In the 1990s he served on a nuclear safety advisory panel established by Ontario Hydro. Resulting from his involvement in these and other studies he became an advocate for nuclear power. As an environmental scientist he warned about the effects on climate of the burning of fossil fuels long before the current controversy associated with the Kyoto Accord.

CNS news

Fehrenbach named VP of PNC

At a special ceremony during the banquet for the 2002 Pacific Basin Nuclear Conference in Shenzhen, China, October 23, 2002, **Paul Fehrenbach** was installed as Vice-President / President elect of the **Pacific Nuclear Council**. Paul, who is head of laboratories at the Chalk River site of Atomic Energy of Canada Limited, was nominated by the Canadian Nuclear Society early in 2002 and elected by the member organizations of PNC.

The PNC is an umbrella organization of nuclear societies and trade organizations from countries around the Pacific rim. Both the Canadian Nuclear Society and the Canadian Nuclear Association are members.

At the same ceremony Dr. Mamoru Akiyama of Japan assumed the role of PNC president from out-going president Prof. Wang, Naiyam of China.

The PNC used the opportunity of the PBNC 2002 conference to hold its semi-annual meeting. Representatives from Australia, Canada, China, Japan, Korea, Russia and the USA attended. At the meeting it was announced that Mike Diekman, a staff member with the American Nuclear Society, had been named "permanent" secretary-treasurer.

One of the roles of the PNC is to authorize the Pacific Basin Nuclear Conferences. At this meeting Gail Marcus, past-president of the ANS, provided an update on the planning for the 14th PBNC which will be held in Hawaii in March 2004. Following a presentation from Neil McDonald of Australia the Council formally approved the bid to hold the 15th PBNC in Sydney, Australia in October 2006. The Russian delegates said they were interested in holding the 16th PBNC in Vladivostok in 2008.

Much of the activity of the PNC is through Working Groups. At this meeting Shami Dua, of AECL, presented an outline of the impressive program being undertaken by the Codes and Standards WG which he heads. Shorter reports were received on the Next Generation WG and Waste Management WG. PNC members suggested that the 14th PBNC have a special session on waste management.

The next PNC meeting will be held in conjunction with the summer meeting of the ANS in San Diego, California, in June 2003.

Outgoing PNC president, Wang Naiyan (L) and incoming vice-president/president-elect Paul Fehrenbach, watch as new president Mamoru Akiyoma addresses crowd at the official transition ceremony of the Pacific Nuclear Council held during the PBNC 2002 banquet, October 23, 2002.

CNS Council exploring scholarship program

Over the past few months one of the major topics being discussed by the Council of the Canadian Nuclear Society is the possibility of creating a scholarship program for CNS members, children and grandchildren.

Among the many factors to be considered are the limitations of the Society as a volunteer organization and the variability of marking standards in high schools across the country. At the time of writing no firm decisions have been made.

Any member wishing to offer comments or suggestions should contact CNS vice-president Jeremy Whitlock who is chairing the committee studying the issue. Jeremy's e-mail address is: < whitlockj@aecl.ca >

Chalk River *(Michael Stephens)*

The branch AGM took place on November 7 in conjunction with a seminar on feeder thinning research at the University of New Brunswick by **William Cook**. Planned talks include Prof. George Bereznai (UOIT School of Energy Engineering & Nuclear Science) at the end of Nov., and Victor Snell on CANDU Safety and Licensing.

Golden Horseshoe *(David Jackson)*

The branch held its main activity, its annual **Nuclear Careers Session** for Engineering Physics students at McMaster University, on Thursday, November 14, 2002.

Representatives from Ontario Power Generation, Bruce Power, Atomic Energy of Canada Ltd., Canadian Nuclear Safety Commission, Nuclear Safety Solutions Ltd., and Candesco gave short outlines of there organizations and then mingled with the students while enjoying refreshments.

New Brunswick *(Mark McIntyre)*

The NB Branch of the CNS was pleased to co-host **Robert van Adel**, President of AECL, at the Sheraton Hotel in Fredericton on September 26, 2002. This lecture took place just two days after the New Brunswick Public Utilities Board recommended there was not a strong financial case to be made, as the contracts are currently negotiated, to the refurbishment of the Point Lepreau Generating Station. Approximately 20 CNS members and 50 members of the Atlantic Resources Industry Association (ARIA) were in the audience. ARIA is a trade organization looking for opportunities in the Atlantic Canadian Energy Sector.

Upcoming events: **Adam McLean**:
late November , 2002 on ITER.

The New Brunswick Branch of the CNS participated in the most recent **Science of Nuclear Energy and Radiation (SONEAR)** Course held in Halifax, Nova Scotia on October 15-17, 2002. Twenty-five science educators from around the province converged on Halifax to hear speakers on such topics as: Introduction to Radiation, Risk and Risk Assessment, Nuclear Power Reactors, Medical Application of Radiation in the Health Sciences, Effects of Low Doses of Radiation, among others. NB Branch Chairman Mark McIntyre declared this the most successful SONEAR course ever held. This was largely due to the keen interest and enthusiasm of the science educators.

Special thanks go out to Clair Ripley, William Cook, John Sutherland, Doug Boreham, the CNS, the QEII Health Sciences Centre and the Nova Scotia Dept of Education for making the event such a success.

This was the second SONEAR course that used the Tammemagi/Jackson "Unlocking the Atom" textbook. The science educators appreciated its comprehensive and easy to read text. Each participant at the Friday evening banquet received an "Ask an Expert" CNS Info card.

Ottawa *(Bob Dixon)*

To assist the CNS in its role as co-sponsor for the W.B. Lewis lecture for 2002, CNS Ottawa branch mailed notices of the meeting to its members and others on its mailing list, and followed up with an E-mail reminder just before the meeting.

The first event of the season was an excellent presentation by **Romney Duffey**, AECL chief scientist on the CANDU ACR on November 21. This talk attracted a number of visitors.

Pickering *(Marc Paiment)*

William Cook gave his presentation on feeder thinning research at UNB on November 6. **Dave Torgerson,** senior vice president of AECL, has been invited to make a presentation on the Advanced CANDU Reactor in late November or early December.

Québec *(Michel Rhéaume)*

A visit of the Polytechnique is being organized for all CNS Québec Branch Members and a special invitation will be extended to Hydro-Québec Senior Managers of the Direction Production Thermique et Nucléaire to attend this activity.

Saskatchewan *(Walter Keyes)*

Over the past six months we have briefed all three political parties on nuclear issues - primarily uranium issues and the role uranium plays in reducing GHG emissions. This is a big thing in Saskatchewan where the emissions reduction equivalent of uranium exports exceeds Canada's total annual emissions. We are providing departmental officials in environment and industry departments with information to assist the two provincial ministers involved in Kyoto discussions.

Sheridan Park *(Parviz Gulshani)*

On 2002 October 03, **Norm Spinks** made a presentation on *"Thermo-Economic Assessment of Advanced, High Temperature, CANDU Reactors (CANDU X)"*.

Toronto *(Adam McLean)*

The Toronto branch hosted **William Cook** (feeder thinning) Wednesday November 6, 2002. This meeting was held at Ontario Power Generation Head Office.

Apart from that, there has been a major update to many of the Toronto Branch web pages.

Two successful courses presented

In September and early October 2002 the CNS ran two courses; one on Reactor Safety the other on CANDU Fuel Technology.

A number of Reactor Safety Courses have been held over recent years at Sheridan Park, Mississauga. This one was held in Kincardine, Ontario specifically for staff of Bruce Power. The CANDU Fuel Technology Course also tried a different venue, this time going to an inn at Elora, Ontario.

A course on CANDU Chemistry is planned for next February and another Reactor Safety Course for later in the spring. Contact the CNS office for further information.

The participants and lecturers of the CNS Reactor Safety Course held in Kincardine, Ontario, September 2002, take time to pose for the camera.

INSC issues revised reports

At its semi-annual meeting held November 17, 2002 in Washington, D.C., in conjunction with the Winter Meeting of the American Nuclear Society, the **International Nuclear Societies Council** issued updated reports on *Nuclear Power and the Environment* and *Radioactive Waste.* Both topics had been included as chapters of the book *Current Issues in Nuclear Energy* issued by the INSC in 1998. Both provide succinct information on their respective topics. In the near future the CNS will be distributing copies to CNS Branches and additional copies will be available from the CNS office.

The INSC is an association of nuclear technical societies around the world with membership representing 41 societies, some of them through the European Nuclear Society which, in turn is an umbrella organization.

Joining the INSC meeting was Neville Chamberlain, current chair of the International Nuclear Energy Academy, a group of distinguished nuclear scientists from around the world. The INSC and INEA have had a formal relationship since 1998 when Dan Meneley was chairman of INEA. Further cooperation was discussed, in particular the participation of INEA members in INSC task groups. In turn Chamberlain asked INSC member societies to consider nominating members for INEA.

CNS Council hosts delegation from Finland

CNS President Ian Wilson looks on as Seppo Merisaari, senior member of a delegation from Finland admires the Inukshuk presented to the visitors at a special dinner meeting in Toronto, October 14, 2002.

On October 14 (Thanksgiving Day) members of the CNS Council and invited guests hosted a dinner for a delegation from Finland visiting Canadian nuclear facilities.

Because of the tight schedule of the 14 member visiting group the meeting with the CNS was restricted to a dinner meeting in downtown Toronto. Nevertheless, those Council members attending reported on a very pleasant gathering combined with considerable information exchange.

Special rate arranged at Courtyard Marriott

The CNS has arranged for a special rate for its members at the Courtyard Marriott in downtown Toronto. This hotel is located at 475 Yonge St. in Toronto, just north of College St

CNS members in good standing are eligible for the following room rates per night (single or double) at the Courtyard Marriott, on a space-available basis:

- From now to 2003 March 31:$119 (except 2002 Dec. 31)
- From 2003 April 1 to 2003 October 31: $159
- From 2003 Nov. 1 to 2003 Dec. 30: $119

To receive these rates you must:

- Reserve only via the Courtyard by Marriott Reservation line: 1-800-847-5705
- Mention the name Canadian Nuclear Society
- Have a credit card ready to guarantee the reservation
- Present confirmation of identification as a CNS member on check-in at the hotel (see below).

In order for members to confirm their membership in the CNS, membership cards will be issued with your receipt for 2003 membership fees. To take advantage of this offer before then contact the CNS office.

New Members

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

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

Wavery Cedrick Graham	SHAW-STONE & WEBSTER
Deepak Dhar	Babcock & Wilcox Canada
Rajendra Jain	AECL
Prabhu S. Kundurpi	Ontario Power Generation
Hooman Javidnia	University of Western Ontario
Jake Andrew Philipson	Bruce Power
Elisabeth Varin	École Polytechnique de Montréal
Eric Davey	Crew Systems Solutions
Abderrazzak Ajaja	Université de Montréal
Peide Shi	Ontario Power Generation
Colin G. Hunt	Canadian Nuclear Association
H.W. (Tony) Hinds	Dynamic Simulation & Analysis Corp.
Danielle Nicole Paré	Assistant Health Physicist
Claudia Lemieux	Canadian Nuclear Association
Yang Yang	University of Western Ontario
Theodor Cicerone	CERNAVODA NPP Unit 1
Daniel J. Kane	Sejant Systems Inc.
Sandra Joan Reeves	Reeves Technologies Inc.
Ken Dias	Ontario Power Generation
Peter A. Szabo	CH2M HILL Canada Limited
Zlatko Catovic	Ontario Power Generation
Thambiayah Nitheanandan	AECL
Barrie P. Cope	GE Canada
Dan Allen White	RCM Technologies Canada Corp
Brian Edward Roberts	Siemens Canada Limited
Clara Greco	AECL
David S. McDougall	AECL
John Sommerville	
Ion Dumitrache	Institute for Nuclear Research Pitesti
Michael Anthony Tidbury	
Keith Allen Miller	N.B. Power
James W. Scongack	
Michael C. Jeans	Acres - Sargent & Lundy
Gabe Balog	Ontario Power Generation
Dan C. Coldwell	Harvest Television International Ltd.

Paul Stiles	Harvest Television International Ltd.
A. Doug Hink	ADH Solutions
Beatrice Howey	
Stefan S. Doerffer	AECL
Bahaa A.J.B. Awadh	AECL
Michael Harazim	Framatome ANP DE & S
Mack Pope	Framatome ANP DE & S
Mounia Berdaï	École Polytechnique de Montréal
Richard Pierre Chambon	École Polytechnique de Montréal
Armando Nava	École Polytechnique de Montréal
Jingyang Sun	École Polytechnique de Montréal
Ron G. Fleck	KINECTRICS
Abraham David Banchik	Comisión Nacional de Energía Atómica
Lloyd R. Hillier	MDS Nordion
Christopher J. Heysel	McMaster University
David Bock	AECL
Ramzi Jammal	Canadian Nuclear Safety Commission
Norman Ball	University of Waterloo
Blair John Fraser	AECL
Farbod Lashgari	RCM Technologies Canada
Hossein Shajii	RCM Technologies Canada
Gerard Peplinskie	RadSafe Canada, Ltd.
Amanda Jayne Kotler	AECL
Lisa Korec	Professional Engineers Ontario
Jennifer M. Zwarych	University of Saskatchewan
Nater Prakash Singh	AECL
Kamyar Hazaveh Hesarmaskan	Ryerson University
George C. Byrtus	
Dan G. Buhoci	OPG/Pickering Nuclear
Peter J. Gowthorpe	Intech International Inc.
Faiz Jajo	AECL

Twenty-Fourth Annual Conference of the Canadian Nuclear Society

Nuclear Revival: An Environmentally Responsible Option

2003 June 08-11
Marriott Hotel Eaton Centre, Toronto, Ontario, Canada

Call for Papers

The Canadian Nuclear Society's 24th Annual Conference will be held in Toronto, Ontario, Canada, 2003 June 02-05. The location is the Marriott Eaton Centre in downtown Toronto.

The main objective of the Conference is to provide a forum for discussion and exchange of views on the technical aspects, challenges and opportunities for nuclear technology in what appears to be a new renaissance for nuclear power. As usual, papers are solicited on technical developments in **all** subjects relating to nuclear technology.

Deadlines

- Receipt of summaries: 2003 January 20.
- Notification of acceptance: 2003 February 17.
- Receipt of full papers: 2003 April 21.

To simplify the submission process, it is suggested that the full paper be submitted (instead of the summary) by the January 20 deadline. This one-step process should shorten the time required for the internal review of papers by the authors' companies.

Guidelines for Summaries

Summaries should be approximately 750-1200 words in length (tables and figures counted as 150 words each). They should present facts that are new and significant or represent a state-of-the-art review. Proper reference should be made to all closely related published information. Summaries should include:

- an introductory statement indicating the purpose of the work
- a description of the work performed
- the results achieved

Guidelines for Full Papers

Full papers should present facts that are new and significant, or represent a state-of-the-art review. They should include enough information for a clear presentation of the topic. Usually this can be achieved in 8-12 pages, including figures and tables. The use of 12-point Times New Roman font is suggested. Proper reference should be made to all closely related published information. The name(s), affiliation(s), and contact information of the author(s) should appear below the title of the paper. **A short abstract of 50-100 words should accompany the full paper.** Abstracts will be collected in an Abstract Book to be used by Conference attendees as a guide to presentations.
[Please note: For a paper to appear in the Conference Proceedings, at least one of the authors must register for the Conference by the "early" registration date (2003 May 1).]

Submission Procedure
(Summaries and Full Papers)

The required format of submission is electronic (Word or pdf). Submissions should be made through the Conference web page at:

http://www.cns-snc.ca/conf2003.html

Questions regarding papers and the technical program

e-mail: cns2003@aecl.ca

General questions regarding the Conference
Denise Rouben, CNS Office Manager
e-mail: cns-snc@on.aibn.com
Tel: 416-977-7620

BOOK REVIEW

The Chemistry of Nuclear Fuel Waste Disposal

Donald R. Wiles

Polytechnic International Press, Montreal, e-mail: < pip@polymtl.ca >

200 pages, 36 figures, 45 tables   Canada $36

Don Wiles was a long-time professor at Carleton University in Ottawa. He studied at McMaster University, M.I.T. and University of Oslo.

This book is addressed at the serious layman. It does not assume prior knowledge in the subject but challenges the reader with a great deal of information presented succinctly. Wiles begins with the basic aspects of radioactivity, nuclear power and the management of radioactive waste. Using knowledge of the various radionuclides in spent nuclear fuel he follows their pathways through the many barriers, manmade and natural, associated with deep geological disposal. He argues that only two radionuclides can reach the biosphere and that would take thousands of years.

This book could be valuable to policy makers and others wishing to be informed about the risks of the geological disposal of spent nuclear fuel.

Publications available

CNSC Annual Report 2001 2002

This attractive bilingual report provides an overview of the activities of the nuclear regulator, beginning with several pages devoted to the topic "Becoming a Better Regulator" followed by a section on "CNSC response to September 11".

Copies are available on request from the CNSC. The e-mail address is: info@cnsc-ccsn.gc.ca

Report of the AECL Research & Development Advisory Panel for 2001

This substantive bilingual report looks back over 10 years of the Panel's work and provides succinct reviews of and comments on the many aspects of research and development at Atomic Energy of Canada Limited in chapters titled: Reactor Core Technology; Safety Technology; Wastes, emissions and Environmental Issues; Next generation CANDU Design; CANDU X Reactor Concept; Heavy Water Processing and Production Technology. Copies can be obtained by contacting Ellen Gallagher at AECL, Mississauga, e-mail: < gallaghere@aecl.ca >

Cancer and General Mortality in Port Hope, 1956 -1997

A pre-publication version of this report was presented at a meeting of the Canadian Nuclear Safety Commission on June 27, 2002. The study was conducted by Health Canada for the Commission. It states, "The results of this study found no overall evidence of an increased elevation of cancer mortality in Port Hope."

Reports available form OECD Nuclear Energy Agency

Following are four recent publications of the OECD Nuclear Energy Agency which is based in Paris, France. The first two are free, on-line or in paper format. Visit their website < www.nea.fr > or contact them by e-mail at nea@nea.fr.

NEA Annual report 2001

This handsome 40 page publication presents an overview of nuclear power activities in OECD countries and descriptions of the many technical programs that the Agency sponsors or coordinates.

Nuclear energy and the Kyoto Protocol

This 52 page report was prepared for the World Summit on Sustainable Development which was held in South Africa August 26 to September 4, 2002. After presenting a brief analysis of the potential contribution of nuclear energy to lowering the production of greenhouse gases it goes on to show that nuclear will have greater importance in the post-Kyoto timescale, i.e., after 2012.

Nuclear energy Data to 2010 in OECD Countries

This report provides detailed information on the current use of nuclear power in OECD countries and projections to the year 2010. The price is $20 (US).

Uranium 2001: Resources, Production and Demand

This is the latest version of this popular annual report, which contains extensive data on uranium resources, production and usage. The price is $74 (US).

Buddy Can You Spare A Paradigm?

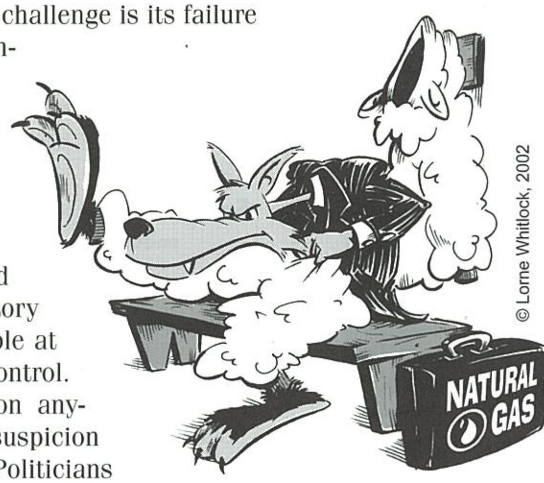
by Jeremy Whitlock

If only nuclear power weren't a million times better than other technologies: If it were only a "few" times more energy efficient. If it could kill only ten times less people than fossil fuels. If it could emit at least a tonne or two of air pollution.

Maybe then the public would be more accepting.

As it stands, nuclear's greatest PR challenge is its failure to conform. Imagine a revolutionary new food a million times more nutritious than conventional products. Social inertia would kill it in the starting blocks.

The masses have difficulty buying into something they can't label. Right wing entrepreneurs and free-marketeers balk at nuclear's history of state involvement. Leftists grumble at the elite they perceive to be in control. Environmentalists eye with suspicion anything big. Economists eye with suspicion anything big and requiring a loan. Politicians eye with suspicion anything big, requiring a loan and seeking their opinion.



Scientists, accustomed to calling a spade a spade, generally have little problem with success. They tend to regard nuclear power as the best thing since sliced wood, but they're largely ignored unless an asteroid is heading for earth, or one of them wants to genetically modify something.

Natural gas knows how to play the game: Be proud that you're half as dirty as coal! Who cares that you're a dwindling resource? You're natural! You're the same technology millions of people have in their basements!

So we have politicians bending over backwards to kiss this blarney stone: Two 800 MW gas plants get approved in Mississauga and Brampton with next to no environmental review, nor public demand for one. The Public Utilities Board in New Brunswick decides that surplus electricity from a refurbished Pt. Lepreau would be an economic risk, while ignoring gas price uncertainty in the same time period. The federal government deletes all mention of "nuclear" from its Kyoto strategy.

Overseas, beleaguered British Energy shells out 100 million pounds a year in climate change ransom that has nothing to do with its nuclear generation. Kyoto negotiators decide it's okay to sell a gas plant to a developing country for CO_2 credits, but not a reactor.

Meanwhile, uber-antinuke group Energy Probe, guerrilla marketing arm of the natural gas industry, has been playing the game with skill for two decades. They care not so much about the environment as they do about pushing their vision of free markets, localized government, and mass privatization.

EP does this by portraying the concerned environmentalist. In the beginning they sang the praises of solar and wind with the rest of the choir -- claiming, for one thing, that the 401 through Toronto should be roofed with solar cells.

In the early-80s they led the fight against nuclear expansion while unabashedly accepting funds from the natural gas and oil industry ("I don't think there's a conflict", says an EP spokesman).

They embraced all the flavours of the week as they came up, and, except for an embarrassing run at the Nuclear Liability Act in the mid-90s, generally kept themselves smelling pretty.

And recurring throughout, like a Bach fugue, was their agenda of capitalism, privatization, and the fuel of choice, natural gas. Understated at first, the true colours now emerge to full fanfare, in step with the times. The new millennium finds Energy Probe with a wide audience and a cultivated media insider network to help reach it: More exposure than ever, and -- as an enterprise profiting from public opinion -- more conflict of interest as well.

The traditional trappings have all but disappeared: solar and wind are passé, it turns out, due to their required subsidization. (EP's distaste for public money does not run so deep, however, as to prevent their own suckling on the teat: charitable tax status, intervener funding, support from government agencies and ministries such as the CBC and HRDC.)

Should nuclear advocates be bitter? Of course not. Snake oil salesmen are as old as commerce itself. When the price of natural gas shoots through the roof, as it surely must, and when the climate change paradigm embraces non-combustion energy technology, as it surely must, all will be well.

But neutrons will never be warm and fuzzy.

CALENDAR

2002

Dec. 5, 6

Symposium on the Scientific and Technical Basis for Protection of the Environment from Ionizing Radiation
Ottawa, Ontario
contact: CNS Office
Tel: 416-977-7620
e-mail: cns-snc@on.aibn.com

2003

Feb. 17, 18

CNS CANDU Chemistry Course
Cambridge, Ontario
Contact: Bill Schneider
B&W Canada
Tel: 519-621-2130 ext. 2269
e-mail: wgschneider@babcock.com

Mar. 18, 19

CNA Annual Seminar
Ottawa, Ontario
Contact: Colin Hunt
CNA
Tel: 613-237-3010
e-mail: huntc@cna.ca

Apr. 2 - 4

International Exhibition on Nuclear Power Industry 2003
Shenzhen, China
Contact: Costal International Exhibition Co. Ltd.
e-mail: general@coastal.com.hk
website: www.coastal.com.hk

Apr. 7 - 11

MARC-6 Methods and Applications of Radioanalytical Chemistry
Kona, Hawaii
website: www.wsu.ed/~rfilby/marc6

April 6 - 10

ANS Mathematics & Computation Topical Meeting
Gatlinburg, Tennessee
Contact: Bernadette Kirk
ORNL
Tel: 865-574-6174
e-mail: kirkbl@ornl.gov

Apr. 20 - 23

ICONE 11 11th International Congress on Nuclear Engineering
Tokyo, Japan
Contact: Jovica Riznic
CSNC
Tel: 613-943-0132
e-mail: riznicj@cnsc-ccsn.gc.ca

May 4 - 7

ICAPP 03 International Congress on Advanced Nuclear Power Plants
Cordoba, Spain
Contact: American Nuclear Society
website: www.ans.org/goto/icapp03

June 1 - 5

ANS Annual Meeting
San Diego, California
e-mail: meetings@ans.org
web: www.ans.org

June 8 - 11

24th CNS Annual Conference and 28th CNS / CNA Student Conference
Toronto, Ontario
Contact: CNS Office
Tel: 416-977-7620
e-mail: cns-snc@on.aibn.com

Sept. 15 - 19

International Conference on Advanced Nuclear Power Plants and Global Environment
Kyoto, Japan
Contact: Atomic Energy Society of Japan
American Nuclear Society

Sept. 22 - 24

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

Oct. 13 - 14

PLIM & PLIX Conference
New Orleans, LA, USA
Contact: Julie Rossiter
Wilmington Publishing Ltd.
e-mail: jrossiter@wilmington.co.uk

Nov. 9 - 13

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

Nov. 16 - 18

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

2001-2002 CNS Council • Conseil de la SNC

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	e-mail	wgschneider@babcock.com
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	e-mail	roubenb@aecl.ca
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	e-mail	walter.thompson@opg.com
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	e-mail	jacksond@mcmaster.ca

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Ken Dormuth	905-823-9040
Ralph Hart	905-689-3197
Ed Hinchley	905-849-8987
Krish Krishnan	905-823-9040
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Dorin Nichita	905-823-9040
Jad Popovic	905-823-9040
Michel Rhéaume	819-298-2943
Roman Sejnoha	905-822-7033
Ken Smith	905-828-8216
Walter Thompson	506-458-9552
Martyn Walsh	905-373-0852
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