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# bulletin

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*Cover Illustration*

The photograph on the cover is a relatively recent aerial view of the Pickering Nuclear Generating Station. In mid February the CNSC accepted the environmental assessment for the re-start of the four "A" units (at the left in the photo).

*(Photo courtesy of Ontario Power Generation)*


CANADIAN NUCLEAR SOCIETY

# bulletin

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# EDITORIAL

## A rational decision

It took two months after their second and final hearing on the matter but the Canadian Nuclear Safety Commission did finally issue, in mid February, their decision that the proposed re-start of the four Pickering 'A' reactors "is not likely to cause significant adverse environmental effects".

The Commission obviously took great pains with the wording of their "Reasons for Decisions" (which are reprinted in this issue of the *CNS Bulletin)* knowing that some of the intervenor groups may challenge the decision. A whole section was devoted to the question of "public concerns". Ontario Power Generation officials had informed the *CNS Bulletin* earlier that they expected a legal challenge but that would not deter them from proceeding on the planned work at the station. The fact that a challenge against the CNSC decision on the waste management project at Bruce was dismissed by the courts gives confidence that any similar challenge to the Pickering decision will not proceed.

What is intriguing in this whole story is the question of why was this prolonged, and expensive, process necessary in the first place. OPG was not building a new plant or drastically altering an existing one. It (or its predecessor Ontario Hydro) had decided to shut down the units to concentrate their efforts on the newer plants after the extensive IIPA review of four years ago showed a number of deficiencies in the operation and management of all of the nuclear plants. Admittedly there was also the matter of the need to upgrade the shutdown systems which is now a major part of the renovations of the station. Nevertheless, it was, in our view and that of many others, stretching the interpretation of the Canadian Environmental Assessment Act to require an environmental assessment for the re-starting of an existing station.

Further, in the process of reviewing the environmental assessment screening report questions of the environmental effect of NOT re-starting plant were ruled ultra vires. That central element of environmental assessment (the examination of alternatives) was raised by several prominent members of the nuclear community to no avail. Given all of the concern over the past few years about climate change brought on by excessive emissions of $CO_2$ that stand defied logic.

In any event that process is now over and OPG can get on with the needed and desired modifications to the Pickering units. They still need to go through a rigorous regulatory review before approval to re-start will be given but it appears that OPG is willing and able to meet all of the CNSC requirements.

Fred Boyd

# IN THIS ISSUE

We start of this issue with a look at CANDU Owners Group Inc. in **The New COG**, a look at this important organization a year and a half after re-structuring itself as an independent, non-profit, corporation.

That is followed by a paper which is representative of COG's work, **Obsolescence of Components,** an updated version of one presented at the CNS CANDU Maintenance Conference last November. Drawing further on that conference there is a paper on **Maximizing the Life of CANDU Fuel Channels.**

Switching to a different viewpoint we have the presentation by Mike Taylor of the Canadian Nuclear Safety Commission (CNSC) on **Reactor Regulation in the Open Competitive Market.** Then, to expand your horizons, there is a dissertation by Alistair Miller on **Heavy Water,** that essential element of the CANDU design

Back to the regulatory scene we have the **Auditor General's Report on the CNSC,** in which we reprint much of the Auditor General's report on the CNSC, together with the Commission's responses. Continuing in the regulatory vein, we reprint the main reasons for decisions by the CNSC to support their acceptance of the environmental report on the re-start of Pickering "A"in **CNSC Rules on Pickering Environment Assessment.**

With the fifteenth anniversary of the Chernobyl accident coming up we present the essence of the report by the United Nations Scientific Committee on Atomic Radiation (UNSCEAR) on the **Radiological Consequences of the Chernobyl Accident.**

There is some **General News,** less than normal since it appears to be a quiet time, and, of course, our section on **CNS News.** Look in that section for registration forms for the upcoming **Annual Conference** in June. Also, please look for the notice about the **Nuclear Industry Winter Seminar,** to be held March 26, 27.

And we close, as has been the pattern over the past several issues, with Jeremy Whitlock's insightful comments in **Endpoint.**

Finally, for the first time in ten years we are including an **Index** of the major articles and papers in the various issues over the past decade.

We hope that you find something of interest in this slightly slimmer issue of the *CNS Bulletin,* and, as always welcome your comments, letters, criticisms, whatever.

## Power plant safety – natural gas vs nuclear energy

Further to my letter in the November Bulletin on the safety analyses we carry out for nuclear plants, I'd like to contrast that with the approach for a large gas-fired plant.

Sithe Energies Inc. would like to build an 800 MW gas-fired power plant in Mississauga, on Winston Churchill Boulevard between Royal Windsor Drive and the Lake Shore Road. The proposed project is in the public information phase of the approval process. The City of Mississauga would like a full environmental assessment of this project, but the Province seems to be *exempting* Sithe from this requirement! Sithe expects Mississauga to approve a change in zoning in February and issue a construction permit this fall.

In the public information meeting, held January 23 in Port Credit, I pointed out that there would be eight storage tanks on the site, holding various chemicals including 4000 USGAL of sulphuric acid, 5000 USGAL of sodium hydroxide and two 50,000 USGAL tanks (~400 tons) of aqueous ammonia (19%). I explained that a natural gas explosion is possible, as the plant would be fed by a high pressure 20 or 24-inch ID pipeline, 1.2 metres below ground level ("Call before you dig!"), yet *no safety analysis has been carried out for this project!*

Sithe stated that the 19% ammonia solution is not considered dangerous. Its most common uses are refrigerating ice skating rinks and fertilizing in agriculture. "Most gas explosions are pipelines not plants. The plants have safety systems that would contain any explosion to the plant."

This might sound reasonable if we ignore the 1979 Mississauga train derailment where a propane tanker car exploded and an adjacent tanker car released 80 tons of chlorine. Fortunately, the thermal updraft of the fire carried the chlorine away, but ~250,000 residents were evacuated for a week while the hole in the tanker car was repaired. Like chlorine, ammonia is a common (window) cleaning chemical. But it is the dose that makes the poison.

Natural gas explosions are quite common. A Yahoo search provides >84,000 items (4220 pages @ 20 items/page). Consider Esso's Longford Plant #1 near Melbourne, Australia. On Friday September 25, 1998, at 12:30 p.m., a series of explosions killed two workers and caused three separate fires. Buildings were damaged by the shock waves. The flow of gas was stopped, and this stopped the supply of 80% of the State of Victoria's gas. The gas supply authority ordered all homes and businesses in Victoria to turn off all gas appliances. Residents living within five kilometres of the plant were evacuated. The pump price of liquid petroleum gas rose, and restrictions were placed on the sale of LPG with a $20 limit per customer. Hospitals canceled or deferred elective surgery, etc. This energy crisis continued for two weeks. The Royal Commission into the accident absolved workers of blame and found that Esso's failure to train its workers was the main cause of the tragedy. Four law firms started a $1.3 billion class action suit against the company for losses suffered by gas users.

The 3-binder Sithe application for a certificate of approval focuses on air pollution concerns; it does not mention safety. It points out that most of our pollution originates from fossil plants in Tennessee; the contribution from the Sithe plant would be negligible in comparison with the other sources. It states that an objective of their plant is to displace coal-fired generation and provide a positive influence on air quality, as well as help Canada meet its commitment, under the Kyoto protocol, to reduce greenhouse gas emissions.

This plant, employing a total of 35 workers, would consume 3.8 x 106 m3/d of natural gas – 5% of the total natural gas usage in Ontario in 1997. "Sithe usage will not affect the reliability of supply to other gas users in Ontario."

Based on the wind pattern in the Sithe report, the chemicals released in a plant explosion will likely drift westward into the Town of Oakville. A southward wind would carry the cloud less than a kilometre to the Clarkson electrical system control centre (for the whole Province of Ontario), affecting our power supply.

Now consider a nuclear plant of comparable output. The CANDU 9 is a Darlington-type reactor in a CANDU 6 building, so we might expect it to be simple to demonstrate that this design is safe. However, a very large number of new safety analyses were needed and the cost was quite significant.

The UNSCEAR 2000 Report shows clearly that nuclear plants are really very safe, *but everyone is ignoring this very important information.* The myths and fears about adverse health effects remain.

There is a serious electricity crisis in California due to a shortage of generation. This is putting major demands on the supply of natural gas, forcing up prices significantly and raising the cost of heating our homes. Several media editorials have suggested that nuclear energy could play a role to help meet the demand without adding to concerns about air pollution and global warming. Ironically, it seems that electricity suppliers and investors can profit greatly by continuing to exploit natural gas. The anticipated economic risks of building nuclear plants, due largely to safety concerns, seems to have turned them away from this option.

The December 2000 OECD/NEA report titled, *Nuclear Energy in a Sustainable Development Perspective,* assesses the extent to which nuclear energy is compatible with the goals of sustainable development. Nuclear energy could play a very important role in many countries, if we would change our attitudes and recognize the safety of nuclear plants. And why is no one concerned about the safety of gas-fired plants?

Jerry Cuttler
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# The *New* COG

## - a look at the CANDU Owners Group, Inc. as it approaches the end of its first full year as an incorporated organization

***Ed. Note:*** *As a further contribution to our on-going series on organizations involved in the Canadian nuclear program, the following article is intended to give readers some insight into the work of the CANDU Owners Group, Inc.*

### Introduction

*"Strength Through Cooperation"* the motto of CANDU Owners Group, Inc., is an apt one which highlights the focus of this unique organization. All the owners of CANDU type nuclear power plants are involved to various degrees in the many programs coordinated by COG, Inc. with the objective of enhancing the performance of the many CANDU plants in Canada and abroad.

COG, Inc. officially came into being in May 1999 when CANDU Owners Group, Inc. was registered as a not-for-profit Canadian corporation. However, COG, as a name and operation, has deeper roots.

### Background

Nuclear power plants are complex machines and the CANDU design shares that characteristic. It is, however, quite different from the light water reactor (LWR) designs used more commonly throughout the world.

The operation, maintenance and upgrading of these machines present many challenges. Facing those challenges the Canadian utilities with nuclear power plants came together in 1984, along with Atomic Energy of Canada Limited, to promote cooperation in research and development, information exchange and specific programs that would lead to improved performance.

The fundamental objective identified by the four founding members (Ontario Hydro, New Brunswick Electric Power Corporation, Hydro Quebec and Atomic Energy of Canada Limited) in the Agreement signed August 1, 1984 was:

> *- to establish a framework for cooperation, mutual assistance and exchange of information as may be found necessary or desirable from time to time for the successful operation and maintenance of CANDU nuclear electric generating stations.*

A Directing Committee was formed to oversee the operation of the group, drawn from senior ranks of the four member organization. The first Directing Committee was chaired by Hugh Irvine of OH, with members, Frank MacLoon, NBEPC, Bernard Michel, HQ, and Gord Brooks, AECL. Barry Collingwood was appointed manager, Ron Page, program manager, and Henry Chan, Information Exchange Officer. Many of that group have retired; Barry Collingwood returned to Ontario Power Generation and Henry Chan is now Program Manager, Joint Projects and Services, with the new COG Inc.

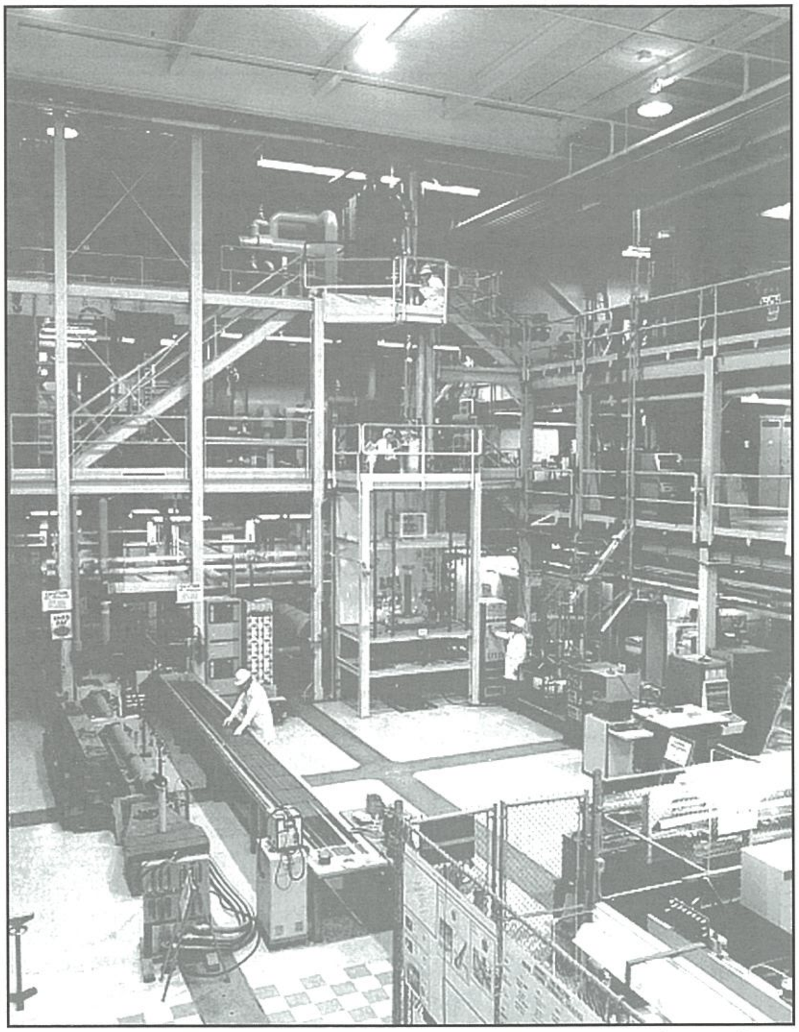
Over the years the COG program and its membership expanded. As early as 1986 the Comision Nacional de Energia Atomica (CNEA) of Argentina and the Korea Electric Power Corporation (KEPCO) joined the Information Exchange Program.

The first full year of operation, 1985, had a total budget of $41.3 million but actual expenditure of just $33.7 million, about half of which was spent on the SLAR (Spacer Locate And Repositioning) project. Almost $15 million was directed to research and development projects related to thermalhydraulics, fuel channels, fuel design and containment. During that first year five technical committees were formed to oversee the programs, beginning a pattern used successfully over the next decade.

In 1987, with the retirement of Ron Page and the growth of the program, three Program Managers were appointed; George Field, John Webb and Jim Walker. That year the total budget reached almost $80 million. The following year a Health and Safety research and development program was added to the four existing ones: safety and licensing; fuel channels; waste management; and CANDU technology, and the total budget grew to $103 million. That year India and Pakistan joined the Information Exchange Program. Four years later RENEL of Romania also joined.

The overall program continued to grow over the next few years, reaching $189 million in 1992, of which $180 was devoted to the R and D programs. Two sub programs, safety and licensing, and, fuel channels, made up about half of the R and D budget. This level of activity continued until 1996 when the R and D program underwent a fundamental restructuring as a result of the federal government cutting AECL's budget and Ontario Hydro taking over the nuclear fuel waste management program. Further, the original COG Agreement expired December 21, 1996. Nevertheless, in fiscal 1996-97 COG financed the building of the Biological Research Facility for animal research at the Chalk River Laboratories.

The year 1998 was a challenging and pivotal year for COG.



*A view of the thermalhydraulics laboratory at the Chalk River Laboratories in which a full length 37 element heater string was used in freon tests examining the effect of high overpower on dryout, a COG organized research project.*

Ontario Hydro expressed reluctance to continue with COG in its existing form and all of the utilities questioned the value of some elements of the R and D program. As a consequence the total budget for 1998-99 fell to $75 million.

In light of these concerns and actions the Directing Committee commissioned John Sommerville, formerly of NBEPC, to conduct an independent review of COG. Among his recommendations was that COG should be incorporated as an independent organization. As noted above, this was achieved in May 1999 with Sommerville acting as interim president. In October of that year Patrick Tighe was appointed president.

## COG Today

The new COG Inc has already become a focussed, effective organization, with a modest sized but highly qualified staff of 27, housed in attractive offices on University Avenue in Toronto, Ontario. Despite a budget much smaller than in earlier years it has, during its first year and a half in its new corporate form,: upgraded its Information Exchange Program, played a key role in defining critical Rand D requirements, established a common set of Industry Performance Indicators, and established a Regulatory Affairs senior position to assist members and develop common approaches to regulatory issues. A major effort is underway to bring closure to the several "generic safety issues" identified by the Atomic Energy Control Board (now Canadian Nuclear Safety Commission).

The current Board of Directors is made up of: Ken Hedges of AECL, chairman; Stu Groom from NB Power; René Pageau, Hydro Quebec; and John Skears, Ontario Power Generation. Senior staff include: Pat Tighe, president; Rod McIvor, treasurer and chief financial officer; Vince Langman, director, R and D; Henry Chan, program manager, Joint Projects and Services; Nino Oliva, director, Regulatory Affairs and program manager, safety and licensing R and D; Malcolm Hardie, program manager, R and D; Chris Guiry, program manager, Information Exchange; and Bernice Brooks, executive assistant.

All of the participants, who now include the Third Qinshan Nuclear Power Company in China and the Nuclear Power Company of India Limited, contribute to a "base program" totaling close to $1 million, which covers the Information Exchange Program, and the overall administration of the R and D and Project and Services programs. The four Canadian members contribute to the R and D program according to an agreed formula, after prior agreement on the content of the program. In 1999 - 2000 the R and D program totalled approximately $24 million. For "other programs" on specific projects, members contribute according to their individual interest.

COG's overall program is divided into three major blocks: Research and Development; Joint Projects and Services; and, Information Exchange.

## Information Exchange:

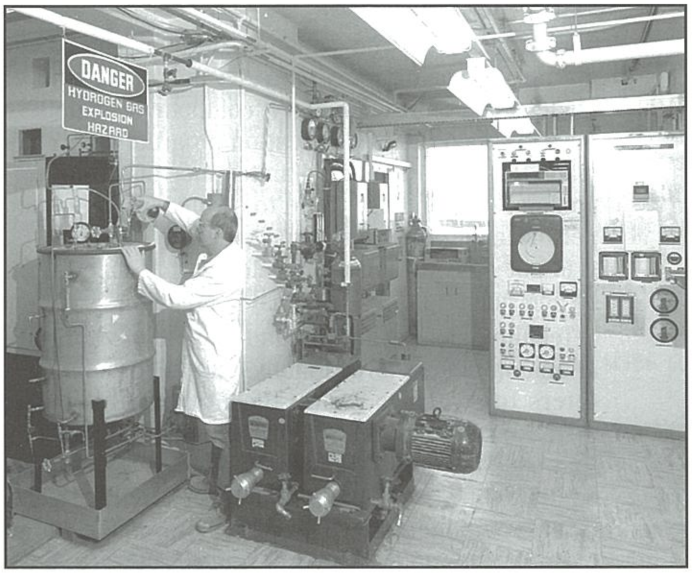
The goal of the Information Exchange Program is to enhance excellence in the safety, reliability, and economic performance of CANDU stations worldwide by sharing operating experience and resolving technical and operating problems for all COG members.

A central component of the Information Exchange Program is COG's recently renewed and upgraded, web site, called COG ONLINE, which is restricted for members' use only. Efforts have been made to make COG ONLINE an easy to use tool for members to interface with each other and with COG. It is a unique Canadian web site providing electronic delivery of vital information to enable COG members worldwide to react quickly and effectively. A specific application is the provision of "Just In Time" briefings to keep members aware of events that could have some bearing on their operations.

Reviving one of the major components of the earlier COG, a renewed emphasis is being placed on organizing workshops. There have already been 16 workshops in fiscal 2000 -2001.

## Projects and Services

A growing program under Projects and Services is that for bulk procurement. By combining their needs for spare parts through COG the utilities are capturing considerable economies of scale. Other on-going programs involve fuel channel surveillance and feeder thinning studies. A modest program continues on the CIGAR inspection device although OPG withdrew from the project in 1999 and retained the head. OPG manages Canada's involvement in the safety review of KANUPP in Pakistan.




*CRL technologist Mark Godin is shown performing a chromate treatment in the H-5 loop.*

## Research and Development

The Research and Development Program accounts for close to 3/4 of COG's overall budget. There are four major components to that program: safety and licensing; fuel channels; chemistry, materials and components; and, health and safety. Safety and Licensing continues to absorb the largest portion of the budget. The focus is the "generic action items" identified by the former Atomic Energy Control Board, now Canadian Nuclear Safety Commission; specifically:

- large LOCA (loss of coolant accident) margins
- hydrogen and fission product source terms
- trip effectiveness criteria
- consequence of pressure tube rupture
- single channel sever fuel under-cooling events
- safety analysis technology development, and,
- fuel design and performance

Using thermalydraulic date from the RD-14M facility at the Whiteshell laboratories and void reactivity measurements in ZED-2 at the Chalk River Laboratories work continues on the validation of various industry computer codes.

A focus of the work on hydrogen is to demonstrate the effectiveness of hydrogen mitigation features in containment based on experiments using the large scale vented combustion and containment test facilities at the Whiteshell Laboratory. Similarly results from experiments in the Burst Test Facility are being used to validate computer codes to predict fission product release in the event of an accident.

Reactor trip effectiveness under accident conditions depends upon the margin to fuel dryout and on the rate of fuel sheath heat-up following dryout. Various codes are being reviewed and modified to provide improved confidence in calculated safety margins.

The potential consequence of a pressure tube rupture has been a focus of study since the beginning of the CANDU program. Part of the current work is to characterize the effect of ageing .of the Zr-2.5Nb material of the pressure tubes.

If the blockage of a single channel reduces coolant flow sufficiently , fuel and channel failure may occur with the consequential ejection of molten material and hot components into the moderator. The resulting fuel - moderator interaction could disable part of the reactor shutdown or control devices. A five year program has been designed to examine this issue experimentally and theoretically.

COG programs on safety analysis technology development are part of an overall industry effort towards the qualification and validation of safety analysis software.

The concern about fuel performance and condition focuses on the ability to identify fuel degradation mechanisms to be able to predict potential failure. Special irradiations have added power reactor data useful in validating codes and developing operating guidelines.

For the future COG's R and D strategy will focus more on operating issues. There is already a move away from the emphasis on safety and licensing to one on life extension. Discussions are underway towards involving the off-shore members in the R and D program.

## In closing

The "new" COG is a much leaner organization than its predecessor of the 1990s but much more focussed on the issues of primary concern of its utility members. That focus and the positive results of the past year should ensure that CANDU Owners Group Inc. will continue to grow as a key organization assisting operators of CANDU plants to achieve high standards of economic and safe performance.

# Obsolescence of Components

## - a challenge for the nuclear power industry

*by Ujjal Mondal*[1]

***Ed. Note:** The following paper is an edited and updated version of one presented at the Fifth CNS International Conference on CANDU Maintenance held in Toronto, Ontario, November 2000, with the title Obsolescence in Nuclear Industry.*

## Abstract

Most nuclear plants around the world are roughly 15 to 30 years old. The design and procurement of CANDU plants took place from the late 60's to mid 80's (i.e., 20 to 30 years vintage). Most equipment originally installed in these plants is obsolete or the manufactures are out of business or their production has been discontinued due to technological evolution. In order to maintain operation of nuclear plants with safety integrity and commercial viability, certain spare parts must be available at the plant all the time.

The objective of this paper is to identify an optimum cost-effective approach that solves obsolescence problem efficiently and without duplicating efforts. The Nuclear Utility Obsolescence Group (NUOG) was formed to address the obsolescence issues collectively by the nuclear industry with participation from the utility members and the suppliers. The NUOG strategy is based upon the principles of sharing. It advocates sharing of obsolescence solutions and concerns among the utilities. CANDU Owners Group (COG) is closely associated with NUOG initiatives and has provided full support.

COG has initiated self-assessment of obsolescence in the members' plants. The purpose of self-assessment is to provide baseline information that would help identification of obsolescence and coordination of their solutions. The following areas are covered in the self-assessment initiative:

- Identification of obsolete components in selected systems in the plant.
- Assess effectiveness of the current obsolescence identification process and in resolution of obsolescence Issues in the plant
- Identification of common CANDU plant design specific obsolescence issues
- Benchmarking of good obsolescence practices followed in the plant

The benefits of Obsolescence Self-assessment would be shared among the COG members. It will also provide an opportunity to solve common obsolescence issues collectively.

The author believes that the initiatives taken by COG would lead to cost-effective and pro-active identification of obsolete components and sharing of solutions among all participating nuclear utilities. The nuclear industry will be the net beneficiary in achieving safer, productive and competitive operation.

## 1.0 Introduction

Most vendors who supplied original equipment are not in business any more. A major segment of nuclear pressure boundary component suppliers have dropped their qualification program and it has made the operation and maintenance of these components challenging. Due to stringent quality and performance requirements of nuclear components, it is not easy to find replacements that meet form, fit and function of the original component.

Technological evolution and demise of traditional analog design forced many equipment manufacturers to switch to digital technology. It accelerated the rate of obsolescence of analog technology that is considered as the workhorse of process controls in all nuclear plants. Customized electronic components face faster obsolescence due to a limited user base which manufacturers have little incentive to support.

This paper discusses the options available to address a wide range of obsolescence issues and how to share the solutions among the utilities. Such initiatives would save a large amount of valuable resources spent by the nuclear power industry and it would allow them to remain competitive.

## 2.0 Problem definition

When the design of most operating nuclear plants were carried out from late sixties to early eighties, no one anticipated major obsolescence of the selected equipment. Most were concerned with obtaining the manufacturers' assurance that the equipment would perform reliably for 40-year pro-

1 Ujjal Mondal is Manager, Joint Projects, CANDU Owners Group, Inc.

jected plant life. The technological advances accelerated the equipment obsolescence in comparison to manufacturers going out of business.

On the other hand, equipment performance is one of the key elements of success in the nuclear business. The industry has recognized that in addition to improvement in the areas of human performance, maintenance of system health and managing the risk of nuclear accidents, equipment performance is one of the essential elements of success in the nuclear power business. The improvement in equipment performance depends on how the utilities address the following:

- Equipment maintenance
- Quality of equipment and its workmanship
- Maintenance of spares

## 3. Impact of Obsolescence in Nuclear Industry

The obsolescence has caused a loss of production in many utilities. The effort spent by Procurement and Component Engineering to find a replacement component has been increasing and the resources has been found to be inadequate to meet the growing needs of their services. Most experts believe that unless something is done sooner by the industry to solve obsolescence problems, the utilities will face a tremendous challenge to keep their nuclear plants economically viable.

In brief, the following are the results of obsolescence in the nuclear industry:

- The obsolescence remains unknown until one tries to buy the component.
- As the parts get old, the aging effect accelerates the failure of components and thus the effect of obsolescence in the plant is further compounded.
- Duplication of efforts makes the nuclear industry less efficient and may be an impediment to its long-term success.

## 4.0 Industry Initiatives

In the US, industry leaders have assessed the degree of threat posed to the nuclear industry due to obsolescence. There have been a number of initiatives in the past to address obsolescence, such as:.

- The Nuclear Utility Obsolescence Group (NUOG) was formed in November 1999 under the leadership of Wolf Creek Nuclear Station. Currently the membership consists of more than 39 nuclear utilities and more than 60 Nuclear Stations around the world. NUOG has developed plans to address obsolescence as a collective approach. COG was a founding member of NUOG.
- COG is working with its members to set up a common database of obsolete items.
- COG is conducting Obsolescence Self-Assessment at its members' plants.

## 5.0 NUOG Initiatives

To address the problem of obsolescence, NUOG has adopted "Principles of Sharing" passed by the CEOs of North American nuclear utilities under the sponsorship of the Institute of Nuclear Plant Operators (INPO).

### 5.1 Principles of Sharing

- "As nuclear professionals, we affirm our commitment to share information with each other to enhance the safe and reliable operation of our nuclear power plants. The cooperation is fundamental to our future success"
- "Not one of us can achieve excellence alone, and not one of us will fail alone"
- "Commercial competition must not erode nuclear operation"

NUOG members believe that they must not duplicate effort and, as a consequence, that a common database will help in the sharing of obsolescence solutions.

### 5.2 Process Development

NUOG has developed Flow Charts, which are pre-cursors of the process that would standardize obsolescence identification and solution. Some of the potential solutions are:

- Surplus Inventory Market
- Special Component Production Run
- Rebuild Program
- Cannibalization
- Substitution
- Reverse Engineering
- Design Change

### 5.3 Database Development

The industry needed a means to exchange information on obsolescence identification and solutions. NUS Information Services has been given the responsibility to set up the "Obsolete Item Replacement Database" (OIRD) linked to the Web based "RAPID" (Readily Accessible Parts Information Directory) database.

## 6.0 CANDU Owners Group (COG) Initiative

The COG initiative is based on COG's basic mandate, "Strength Through Cooperation". Sharing of information on obsolescence is clearly an area that will reduce the individual utility effort in solving this difficult issue. As a first step, COG has initiated *Obsolescence Self-assessment* to identify programmatic issues in dealing with plant obsolescence and identification of obsolete components. The obsolescence identification and strategy evaluation is a pro-active process. The self-assessment process also identifies the strengths applicable to plant. Obsolescence Self-Assessments have been completed at Bruce B (September 2000), Gentilly 2 (October 2000) and Pickering B (November 2000) Nuclear

Stations. Obsolescence Self-Assessment for Darlington Station has been planned for March 2001.

### 6.1. Selection of Systems

The assessment is conducted on 10 systems important to safety and power generation or where obsolescence has threatened the performance of system functions. The systems are generally selected from the following list:

| | |
|---|---|
| Moderator System | Emergency Core Injection System |
| Primary Heat Transport System | Liquid Zone Control System |
| Emergency Power Supply System | Digital Control Computers (DCC) |
| Airlock and Transfer System | Reactor Regulating System |
| Negative Pressure Containment | Shutdown System I (SDS 1) |
| Turbine Supervisory Equipment (TSE) | Shutdown System II (SDS 2) |
| Electrical Class I/ II Power Supply System | Standby Generator |

### 6.2. Identification of Obsolete Components

The first task of the assessment process is the gathering of data on system components. Traditional sources are: Passport; the Master Equipment List (MEL); Instrument Schedule; Valve List; Technical Specification Sheets; etc.

The next step is to identify obsolete components found in the list via expert knowledge, contacting the vendors to obtain the status of availability of components manufactured or supplied by them.

### 6.3. Recommendation of Replacement Strategies

The last step in the self-assessment is to recommend replacement solutions. The recommendation covers suggestions of replacement components made by the suppliers or the manufacturers. The plant procurement or design engineering group needs to evaluate those suggestions and accept or reject them.

### 6.4. Self-Assessment Process

During the week of in-plant self-assessment, the assessment team meets the plant staff members performing functions of: Maintenance, Components and Equipment Engineering, Procurement Engineering, Materials Management, Inventory Management, Plant Design Engineering, System Performance, etc., to obtain their feedback on various obsolescence issues and component replacement. Good benchmarking processes are also identified during the interview process.

### 6.5. Obsolescence Database

COG is creating a web-based Obsolescence Database for participating members. This database is used to identify common obsolescence issues, common solutions, etc.

### 6.6. Self-assessment Reports

Self assessment reports list the obsolete items found in the Self-assessment process, replacement solutions of obsolete components, programmatic issues, benchmarking good practices in the assessed plants and recommendations. These reports will be available to all participating COG members.

Phase 1 Report: After completion of self-assessment at a plant, the report identifies obsolescence issues, programmatic issues, good bench-marking processes etc. as listed above.

Phase 2 Report: After completion of Self-assessment at all participating COG member plants, the report will identify common issues, common solutions available at a replacement CANDU assessed plants.

### 6.7. Obsolescence Database

An Internet web based Obsolescence Database has been created for the use of the participating COG members. The data is analyzed further to identify common obsolescence issues, potential common solutions etc. COG intends to download obsolescence data or create an Internet link with the NUOG Obsolete Items Replacement Database (OIRD). OIRD can be accessed through the RAPID Website.

### 6.8. Development of Common Solutions

COG's Joint Projects section will coordinate the development of common solutions, where such issues are identified in the COG database. The process requires participation of all members and their full support. COG believes that such an initiative will save all its members valuable resources by avoiding duplication of effort and engaging the best resources from the participating utilities.

### 6.9. COG Bulk Purchase

COG will initiate Bulk Purchases where a larger volume would reduce the cost of equipment and increase the potential for the manufacturer to establish the manufacturing run for the identified component. COG has been involved in such initiatives in the past which were very successful.

## 7.0 Self-Assessment Results

The assessment results are reasonably consistent among the CANDU plants. Electrical components appeared to have faced most obsolescence. These components did not undergo major technological evolution in comparison to instrument and control (I&C) components. Each assessment report provides a short list of critical components that faced obsolescence. The following are brief details of assessment findings:

### 7.1. Bruce B Nuclear Station

948 unique items were reviewed. 58 critical obsolete items were found to have no spares in the inventory. Most of these items perform critical functions in the plant. A partial list has been attached in Appendix A to demonstrate the extent of obsolescence at a nuclear station. Electrical components appeared to have faced maximum obsolescence (34%) in comparison to 27% for I&C. Mechanical components experienced least obsolescence (12%) among the components analyzed.

### 7.2. Gentilly 2 Nuclear Station

1131 unique items were reviewed. 174 obsolete items were found to have no spares in the inventory. Most of these items perform critical functions at the plant .I&C components appeared to have faced maximum obsolescence (26%) followed by Electrical 25%. Mechanical components experienced least obsolescence (14%) among the components analyzed.

### 7.3. Pickering B Nuclear Station

395 unique items were reviewed. 21 obsolete items were found to have no spares in the inventory. Most of these items perform critical functions at the plant. Electrical components appeared to have faced maximum obsolescence (32%) followed by Mechanical 17%. I&C components experienced least obsolescence (16%) among the components analyzed. The data analyzed may not be representative due to the small sample size in comparison to those of Bruce B and Gentilly 2 Nuclear Generating Stations.

## 8.0. Conclusion

Obsolescence is a major concern that has the potential to degrade viability of the current nuclear power business. In the nuclear industry, the solution to the replacement of obsolescent equipment has a severe impact, due to component qualification requirements, maintenance of design basis, configuration management, software qualification, etc. COG believes that the utilities are ready to respond to sharing spares and solutions. This strategy will improve the performance of nuclear plants and enhance its competitiveness.


## Acknowledgement

The author wishes to thank Messrs. Patrick Tighe and Henry Chan of COG for reviewing the paper and providing solid support in the Obsolescence Self-Assessment initiative.


## APPENDIX A

Obsolete Items with No stock identified at Bruce B Station (Partial List)

1. Agastat Time Delay Relay 2122DH used in SDS2 System,
2. Bach Simpson Meters – Model # 3624X.-all systems (lack spares in most areas)
3. Bestobell fi" Globe Valve (EQ) used in SDS2 System,
4. Brooks Instrument, Model 7900A01A2A1 alarm meter used in ECI System,
5. Burckhardt Relief Valve, Model 83CM46 (EQ), used in ECI System,
6. C&D Technologies Battery, Model # LC 21 232 used in Class I/II System,
7. Canadian General Electric, Dynamic Signal Compensator, Model # 134D9544G1 (EQ) used in SDS1 System,
8. Canadian Westinghouse 250V DC Breaker, Model # EHD3100S, used in Class I/II System
9. Clare Pender Mercury wetted Relay, Model # HGS5015 (EQ) used in SDS1 System,
10. Consolidated Safety Relief Valve 1" NC3-600#X 1-1/2" 150# (EQ) used in ECI System
11. Dezurik 6" Motorized Butterfly Valve, Model # 632 used in Class III Systems,
12. Fischer and Porter Controllers, 53EL, ED series-used in most systems (lack spares in most systems),
13. Fairchild Relay, Model # 21212D used in ECI System
14. Fisher Controls, Regulator 67AFR 224/226/239 (EQ) - used in most systems,
15. Guelph Engineering Check Valve, 6" (300#), NC 1 (EQ) used in Moderator System,
16. Gulton Industries Alarm Modules, Model # GA46 used in Standby Generator,
17. Gulton Industries Temperature Switch, Model # GA46-016/18 used in Standby Generator,
18. Hewlet Packard Power Supply, Model # 618C used in SDS1 System,
19. Honeywell Switch, Model # 4089 used in ECI System,
20. Honeywell Limit Switch, Model # 1HS6 used in HT and ECI Systems,
21. Ingersoll Rand Centrifugal Pump NC3, Model 6X13LP (EQ) used in Moderator System,
22. Keane Controls Solenoid Valve, Model # 5014202 (EQ), 48V DC used in ECI System,
23. Keithley Ion Chamber Amplifier (EQ), used in SDS1
24. Klockner Moeller MCC, Model # DIL 3-22-N used in Class III System,
25. Leslie Y Strainer, Model # 7510NX used in LZC , Moderator and HT Systems,
26. Martonair /' 3-way valves, Model # C441/86 used in Airlock System.
27. Matheson Pressure Regulating Valve, Model # 3104C (EQ) used in ECI System
28. Norgren Filter, Model # B-6TF-7 with manual drain used in Airlock System,
29. Penberthy Level Gauge, Model # C15T (EQ) used in ECI System (1 in stock),
30. Rochester Temperature Transmitter, Model # XSC-1370 used in HT and ECI Systems,
31. Rockwell Accumulator used in ECI System (2 in stock)
32. Rosemount 100 ohm RTDs, Model # 104 (EQ) used in ECI and SDS2 Systems,
33. Sarco Strainer, Model # YBW, 6", 150# used in Moderator System,
34. Siemens Canada Compressor, Model #2BZ 2089-9Z used in LZC System, Sigma Meters, Model # 9263 X used in various systems,
35. Simpson Meter, Model # 2865DP used in Class I/II Systems,
36. Staticon Inverter 2kVA, Model # CR40F2DC used in Class I/II Systems (1 in stock),
37. Taylor Forge Check Valve, Model # DRV-Z1-1/2", 300# used in LZC System,
38. Tele Radio System Shut-off Rod Clutch Controls Bank 2 Module B, used in SDS1

# Maximizing the Life of CANDU Fuel Channels

*by H. Wong[1], P.J.Ellis[2], R. Baker[3], P. Gauthier[4]*

***Ed. Note:** The following paper was presented at the 5th CNS International Conference on CANDU Maintenance held in Toronto, Ontario, November 2000.*

## ABSTRACT

The fuel channel of a CANDU® nuclear power plant is comprised of a Zr-2.5Nb pressure tube connected to two stainless steel end-fittings, a Zircaloy-2 calandria tube (in contact with the moderator), and four spacers maintaining the annular gap between the pressure tube and calandria tube. The pressure tubes contain the $UO_2$ fuel, operate at a temperature ranging from 250°C at the inlet to 315°C at the outlet and are subjected to an internal pressure of about 10 MPa. These operating conditions cause changes in the pressure tube dimensions due to irradiation creep and growth, changes in the mechanical strength and fracture toughness, and an increase in the equivalent hydrogen concentration resulting from corrosion of the pressure tube by the heavy water.

Results from pressure tube inspections, examination of surveillance tubes and research and development programs are used to provide an overview of the following pressure tube aging mechanisms:

- axial elongation
- diametral expansion and wall thinning
- sag
- deuterium ingress
- delayed hydride cracking velocity
- fracture toughness

The inspection requirements for establishing an aging management strategy and plan for maximizing the life of the pressure tubes are also presented. Current strategies being employed by Ontario Power Generation, New Brunswick Power and Hydro Quebec are discussed.

## 1.0 Introduction

The fuel channel of a CANDU® nuclear power plant comprises a Zr-2.5Nb pressure tube connected to two stainless steel end-fittings (in contact with the primary coolant), a Zircaloy-2 calandria tube, and four spacers maintaining the annular gap between pressure tube and calandria tube. The pressure tubes are the primary containment of the high temperature $D_2O$ and they are subjected to high stresses and fast neutron fluxes which cause changes in the dimensions and material properties.

Monitoring of the condition of the fuel channels is an important part of the operation and aging management of a CANDU® plant. This paper will focus primarily on aging management of pressure tube performance as the other fuel channel components have not caused significant problems and are not required to be inspected on a regular basis.

## 2.0 Aging Mechanisms.

Under normal operating conditions the pressure tubes are exposed to an operating environment of high temperature (250 to 315°C), high internal pressure (9 to 11 MPa) and high flow rate $D_2O$ coolant. The tubes also experience a fast neutron flux of up to $3.5x10^{17}$ $n.m.^{-2}s^{-1}$. These conditions result in the following aging mechanisms being experienced by the tubes.

### 2.1 Creep and Growth.

Thermal creep, irradiation creep and irradiation growth, resulting from the above operating conditions, cause axial elongation, diametral expansion and wall thinning of the pressure tubes. In addition, since the fuel channels are horizontally oriented, the previous factors, along with the weight of the fuel and $D_2O$ coolant, also result in creep sag of the channel.

### 2.2 Corrosion.

The internal surfaces of the pressure tube and the stainless steel end fitting are exposed to and corroded by the slightly alkaline (pH10) $D_2O$ coolant. A fraction of the deuterium released by the corrosion process is absorbed and retained by the pressure tube. Deuterium migration through the end fitting is released to the Annulus Gas System and to the pressure tube.

1 Atomic Energy of Canada Limited, Mississauga, Ontario
2 Ontario Power Generation, Toronto, Ontario
3 New Brunswick Power, Point Lepreau NGS
4 Hydro Quebec, Centrale Nucleaire G-2

### 2.3 In-Service Damage and Wear

The initial dry fuel loading and the on-power refuelling of the horizontally oriented pressure tubes has caused minor scratching of the lower quadrant of the tubes by the fuel bundle bearing pads. The use of stainless steel shims during initial fuel loading, in recent years, has eliminated the scratching at this stage. Examination of removed tubes has shown that the scratches are rounded and shallow and tests have shown that they are unlikely to cause Delayed Hydride Cracking (DHC) initiation under reactor operating conditions.

The high flow rate of the coolant through the fuel bundles causes bundle vibration which results in minor fretting of the tube wall by the bearing pads. In reactors with a 12 bundle fuel string (i.e. all CANDU 6 and Pickering units), experience from the examination of removed tubes and from the many periodic and in-service inspections performed to date, has shown that these fret marks are shallow and are not likely to initiate DHC. In reactors with a 13 bundle fuel string, fuel bundle bearing pad fretting in the inlet rolled joint area, particularly at the burnish mark, has resulted in deeper fret marks.

Lithium Hydroxide (LiOH), used to control pH in the Primary Heat Transport System (PHTS), can concentrate under the fuel bearing pads due to local boiling effects. This concentration of LiOH under some fuel bundle bearing pads, mainly in the outlet half of the fuel channel, has resulted in crevice corrosion in some tubes. Examination of removed tubes has shown that the pits are wide and very rounded. These are not considered to be sites for the initiation of DHC.

Debris can possibly come from material left in the Primary Heat Transport System during construction/installation, from in-service degradation of components, or from use of unfiltered make-up water to the PHTS. Debris which becomes entrained in the coolant and then trapped in the fuel bundles or between the bundles and the tubes can result in debris fretting damage of both the fuel sheaths and the pressure tubes. The fret marks in the pressure tubes can be deep and may require tube removal, although cracking or tube failure have not been observed. The occurrence of severe debris fretting in pressure tubes is of a low frequency and random thus it is not seen as a generic aging mechanism.

### 2.4 Hydride Blister Formation.

Vibration of the pressure tubes caused by installation activities, such as rolling the pressure tube into the end fittings, commissioning and operation has been found to cause migration of some loose fitting spacers away from their design locations if the spacers are not sufficiently pinched between the pressure tube and the calandria tube. This displacement, if sufficient, allows the pressure tubes to sag into contact with their calandria tubes. If the hydrogen equivalent concentration at the point of contact is above a threshold value then hydride blisters can start to form.

### 2.5 Material Property Changes.

Irradiation of the Zr-2.5 Nb pressure tube material causes hardening of the metal structure, an increase in the yield and tensile properties and a decrease in ductility and fracture toughness.

## 3.0 Overview of Available Inspection Results and Strategies

The following sections provide a brief overview of pressure tube inspections performed to address these ageing mechanisms. Where appropriate, the status of maintenance activities required to maximize the life of the pressure tube is provided.

### 3.1 Dimensional Changes

During reactor operation, the conditions of temperature, stress and neutron flux change the dimensions of the pressure tubes. Irradiation-induced and thermally induced deformation of fuel channel components will, in the absence of other mechanisms, eventually establish fuel channel life. The following inter-related dimensional changes occur in pressure tubes during normal reactor operation:

- axial elongation
- diametral expansion
- wall thinning
- sag

#### 3.1.1 Axial Elongation.

Pressure tube axial elongation due to irradiation can require remedial action, and, in the extreme, become a tube life limiting factor if the bearing length provided by the design is not sufficient to accommodate the projected axial elongation for the design life. The difference in axial elongation rates between neighbouring channels is also monitored to ensure that interference between feeders or problems with fuelling machine access do not occur.

In Point Lepreau, elongation of all fuel channels is measured using the fuelling machine. For Gentilly-2, Pickering B, Bruce B, and Darlington reactors, elongation of all fuel channels is measured periodically during planned outages using specialized gauging tools.

This 100% inspection approach provides information on the elongation rate of each individual channel as well as providing data to determine the variability in the creep and growth properties of the tubes. This information is primarily used to determine the appropriate time for reconfiguration of the channels and for verification of feeder and other fuel channel component clearances. One end of the fuel channel is initially restrained and the other end allowed to move outwards. Reconfiguration involves reversing the fixed and free ends of the channels at about mid-life.

Current understanding of irradiation induced axial elongation indicates that elongation rates may be slightly non-linear, Figure 1. Therefore continued frequent monitoring is required to determine when the channels will go off bearing and to identify which channels are affected and will require remedial action. If the channels are predicted to go off bearing before the design life is reached, the following actions can be implemented:

- shifting the channels to recover any available bearing travel on the current fixed end
- defuelling a small number of channels
- replacing a small number of channels
- demonstrating that off bearing operation is acceptable

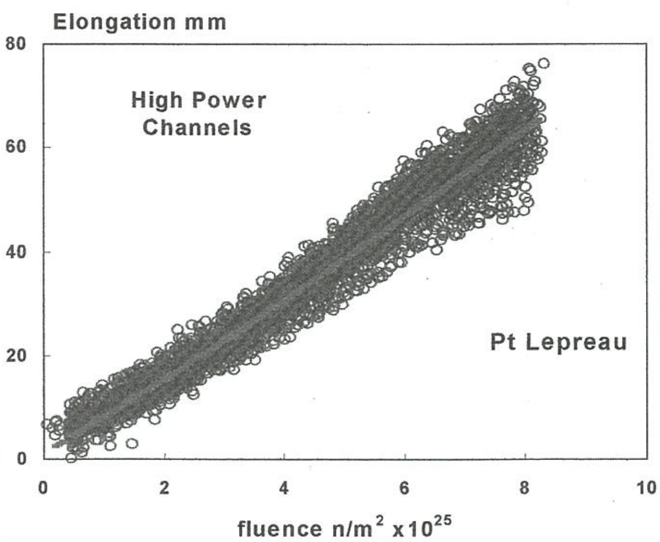



Figure 1: Elongation vs fast neutron fluence (E>1MeV) in a CANDU 6 reactor.

### 3.1.2. Diametral Expansion and Wall Thinning.

The design of fuel channels has taken into consideration the following factors related to pressure tube diametral expansion and wall thinning due to creep and growth:

- stress
- creep ductility
- flow by-pass
- spacer nip up (no gap between the pressure tube, calandria tube and spacer)

Diametral expansion occurs mainly by irradiation creep [1]. For operating reactors, stress analyses to address strength requirements have been performed for operation of pressure tubes to 5% diameter increase and 0.368 mm wall thinning. Based on data from in-reactor experiments 5% is considered to be a very conservative limit with respect to creep rupture and creep ductility, Ells et al. [2].

Diameter measurements have been obtained from Point Lepreau, Gentilly-2, Pickering B, Bruce B and Darlington reactors. These limited results have suggested that the fastest creeping tubes in CANDU 6 pressure tubes are experiencing an upper bound diametral expansion rate of about 0.2% per 7000 EFPH. Based on this upper bound rate, the following is predicted for the fastest creeping pressure tubes:

i Nip-up will occur before design life

ii Diametral strain of 5% will be reached before design life

Pickering B and Bruce B pressure tubes have lower diametral strain rates because of the lower operating temperature and flux. Data from these reactors currently suggest that the maximum diametral strain will not exceed 5% during the design life. Additional data is planned to be obtained from Darlington reactors to calculate representative deformation rates.

It is also now recognized that the measured pressure tube diametral expansion rates will result in flow by-pass and a reduction in margins on cooling capability for the fuel. Because the operation of a unit depends upon the prediction of the maximum pressure tube diameter in the core, there may be a need to obtain additional data on high power channels to more precisely determine the distribution of diameters in each unit and to identify the fast creeping pressure tubes such that remedial action can be taken, if required.

Life management strategies therefore have been or are being developed to evaluate the need for increased inspections. As the units age, these inspections are required to more precisely quantify the variability in diametral expansion to address the following:

- strength and creep ductility requirements for operation with diametral strains greater than 5%
- coolant flow bypass around the fuel bundles for diametral strains greater than 5%
- operating in a "nipped-up" condition (i.e. with no gap between the pressure tube, calandria tube, and spacer).

### 3.1.3. Sag

Sag occurs by irradiation creep from the weight of the fuel and heavy water in the pressure tube. Gross sag deformation of the fuel channel is primarily controlled by the relatively cool calandria tube [3]. There are several limits to pressure tube/fuel channel sag that must be monitored:

i calandria tube contact with horizontal structures that are perpendicular to the fuel channels: the liquid injection shutdown nozzles and horizontal flux detector guide tubes;

ii pressure tube to calandria tube contact leading to blister formation;

iii pressure tube sag leading to fuel bundle passage problems.

Measurements at Bruce Unit 4 in 1993 indicated that the gap between the calandria tube and the LISS nozzles was greater than the predictions and that contact would likely not occur before the design life. Additional measurements are, however, required to appropriately determine the rate of gap closure and confirm that contact will not occur before the design life. Similar measurements are required in CANDU 6, Bruce B, Pickering B and Darlington units to confirm if and when remedial action is required.

To maximize the life of the channels with respect to potential contact with horizontal mechanisms, the current strategy is to perform in reactor gap measurements so as to determine when contact could occur and to identify which channels would be affected. To address channels predicted to be in contact prior to the design life, the following remedial actions could be implemented depending on when contact is predicted to occur relative to the design life:

- perform testing to demonstrate that fretting between the components would be acceptable
- defuel the channel in contact with the liquid injection nozzle or the horizontal flux detector to remove contact
- adjust the tension on the liquid injection nozzle to increase the sag rate of the nozzle
- replace the liquid injection nozzle with an offset design
- replace the calandria tube

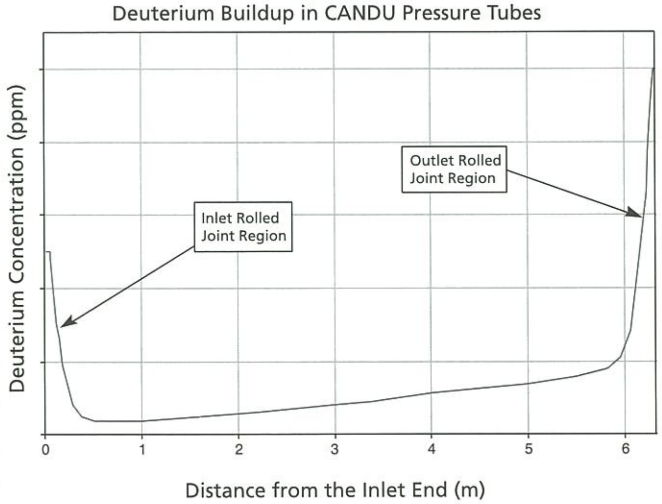
Potential pressure tube to calandria contact resulting from movement of the loose fitting spacers is addressed by inspections to detect the spacers and reposition them, if required. To ensure that pressure tube to calandria tube contact does not occur, the repositioned spacers must be both adequately loaded so that they do not move after being repositioned and appropriately located so that the pressure tube will not sag onto the calandria tube.

Fuel bundle passage, as proven by tests using predicted end of life curvature is not impaired during the fuel channel design life.

### 3.2 Corrosion and Deuterium Ingress.

During reactor operation, the heavy water flowing through the pressure tubes reacts with their inside surfaces forming a zirconium oxide film and releasing elemental deuterium. The loss of metal from this reaction is very small and does not limit the life of the pressure tube.

Figure 2
Deuterium Buildup in CANDU Pressure Tubes



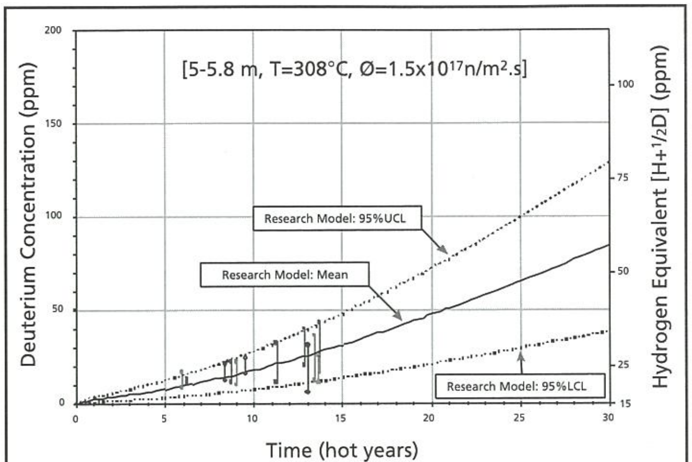




Figure 3: Comparison of Model Predictions of Deuterium Pickup to that measured in CANDU 6 Pressure Tubes

However some of the released deuterium enters the pressure tube increasing the susceptibility of flaws in the pressure tube to crack initiation and growth by delayed hydride cracking (DHC) and potentially decreasing the fracture toughness if very high levels were eventually reached.

Additional deuterium also enters the pressure tube end by crevice effects at the rolled joint resulting in the typical deuterium concentration profile along the tube as shown in Figure 2.

Deuterium ingress in the body of the pressure tube is monitored using a tool which takes small samples from the inside surfaces of the pressure tubes in situ or by punching through-wall coupons from tubes removed from service. The resulting specimens are analysed for deuterium content. Pressure tube sampling campaigns (for hydrogen/deuterium concentration measurements) have been completed in Pickering B, Bruce B, Darlington, Point Lepreau and Gentilly-2 reactors. These results continue to show a low deuterium ingress rate relationship with time. Repeat scrapes however indicate that the ingress may be increasing with time. Figure 3 shows how the observed deuterium concentration is increasing with time in the body of the tube. Monitoring is required to confirm this trend.

### 3.3 In-Service Damage.

There are two primary types of in-service damage; inlet rolled joint fuel bundle bearing pad fretting and debris fretting. Inlet rolled joint fretting affects only the 13 fuel bundle channel design used in Bruce and Darlington reactors. With this design there is interaction between the pressure tube at the inlet rolled joint burnish mark and the fuel bundle bearing pads. The rolled joint may have a higher stress and has a higher hydrogen equivalent concentration and hence may be more susceptible to delayed hydride cracking if flaws are present. A total of about 18% of the Bruce B pressure tube inlet rolled joints and 12% of the Darlington inlet rolled joints have been inspected to date. These inspections have generated sufficient information to characterize the severity and distribution of the inlet fretting in these units. The combination of research data and data obtained from removed tubes make it possible to disposition all tubes with such flaws for continued service.

Inadequate cleanup after construction and commissioning and isolated operational incidents have led to debris entering the Heat Transport System. Debris which is carried around the circuit by the coolant and then trapped in the fuel bundles, or between the bundles and the tubes, can result in wear of both the fuel sheaths and the pressure tubes. Full length volumetric inspections have been completed in Bruce B, Pickering B, Darlington, Gentilly-2, and Point Lepreau. These inspections have indicated that the level of debris fretting is unit dependent. Because of the random nature of this fretting mechanism, it is difficult to predict the location and severity of potential fretting. To ensure that debris fretting that may exist in a particular reactor core will not result in an unacceptably high probability of tubes being susceptible to DHC, the following programs are used to complement the limited volumetric inspections.

- Deuterium monitoring program. This is important because debris frets in the body of the tube are not considered to be an integrity concern if the hydrogen equivalent concentrations in the pressure tubes remain below the terminal solid solubility limit at normal operating temperatures at the flaw tip.
- Additional volumetric inspections to assess the distribution of debris fret geometrics in a core.
- Probabilistic core assessments to establish the probability of initiating DHC from this mechanism.
- Pressure - temperature limits to avoid full pressurization of the pressure tubes at conditions when DHC can occur, i.e., when the hydrogen concentration exceeds the terminal solid solubility limit and to ensure that there are adequate margins against fracture at all operating temperatures.
- Fuel failure monitoring. Debris can cause wear of the fuel sheaths and can be an indicator of wear of the pressure tube.

### 3.4 Material Properties.

Neutron irradiation of the Zr-2.5Nb pressure tube material causes hardening by the creation of dislocation loops which block dislocation movement. This results in an increase in yield and tensile strengths and a decrease in ductility and fracture toughness. The velocity of DHC also is increased. The extent of these changes varies along the length of the tube, from inlet to outlet. The mechanical property changes due to irradiation damage saturate relatively early in reactor operating life, at between 1 and 3 x $10^{25}$ n.m2, E >1 MeV, which represents between about 1 to 5 years of reactor operation. After saturation the rate of change is slow, Hosbons et al. [4].

The existing fracture roughness database has come from both full-sized burst tests and small compact toughness (CT) specimens made from ex-service pressure tube material or from material irradiated in test reactors. The database provides values of fracture toughness for use in structural integrity assessments. Irradiation of CT specimens in high flux reactors allows end-of-life fracture toughness data to be obtained ahead of the operating reactors. The material surveillance program under CAN/CSA N285.4-94 verifies that the tubes in reactor are responding the same way as the CT specimens in the high flux facilities. The most recent surveillance results, from a tube removed from Bruce Unit 3 after 123,450 EFPH of operation and 17.6 x $10^{26}$ n/m$^2$ (E > 1 MeV), support the expectations of fitness for service to the design life from a fracture toughness perspective.

## 4.0 Summary

Aging management of CANDU® pressure tubes requires a strategy that effectively addresses all aging mechanisms so that the core remains fit-for-service. The two key aspects of the strategy are: 1) appropriate inspections involving measurement of axial elongation, radial expansion, and sag of the tubes as well as volumetric inspection for flaws and monitoring of the deuterium concentration; and 2), material surveillance to confirm the acceptability of the fracture toughness and delayed hydride cracking characteristics of the material as it ages.

The key issues being addressed by the current aging management programs are when deformation related design limits will be reached and the impact of future deuterium ingress rates on DHC characteristics and fracture toughness of the material. To maximize the life of the channels, the timing of when remedial action is required and the identity of the affected channels must be known so that appropriate maintenance can be implemented in a timely manner.

## References


1. Christodoulou, N., Causey, A.R., Holt, R.A., Tome, C.N., Badie, N., Klassen, R.J., Sauve, R. and Woo, C.H., Proc 11th *International Symposium on Zirconium in the Nuclear Industry*, ASTM STP 1295, 1996, pp. 518-537
2. Ells, C.E., Ibrahim, E.F. and Causey, A.R., *Proc. International Conference on Creep*, JSME/IMechE/ASME/ASTM, Tokyo, 1986, pp. 59-64.
3. Badie, N, Morandin, G.D. and Sauve, R., Proc. ASME Pressure Vessel and Piping Conference, Boston, 1999, Vol. 385, pp. 247.253.Hosbons, R.R., Davies, P.H., Griffiths, M., Sagat, S. and Coleman, C.E. Proc. 12th International Symposium on Zirconium in the Nuclear Industry, ASTM STP 1354, 2000, pp 122-138.
4. Hosbons, R.R., Davies, P.H., Griffiths, M., Sagat, S. and Coleman, C.E. *Proc. 12th International Symposium on Zirconium in the Nuclear Industry*, ASTM STP 1354, 2000, pp 122-138.

# Reactor Regulation in the Open Competitive Market:

## - Challenges in Regulation, Safety, and New Approaches

*by Michael Taylor*

***Ed. Note:** On February 20, 2001, Michael Taylor, Deputy Director General of Reactor Regulation at the Canadian Nuclear Safety Commission spoke to the Sheridan Park Branch of the Canadian Nuclear Society. Following is the text of his remarks, edited slightly for the print version.*

### Introduction

This paper deals with a phenomenon which is being seen worldwide by the nuclear community - the opening of electricity markets to competition. Those in the nuclear industry are well aware of the developments in Europe and the United States and of the past and pending changes to the nuclear power industry in Canada, particularly in Ontario. However, from my viewpoint, the circumstances that have arisen in Canada over the past few years have a special twist to them in terms of the coincidence of some unique features.

Firstly, there is the opening of the Ontario electricity market itself, currently planned for later this year. This is part of a provincial initiative that has seen the splitting up of the old Ontario Hydro and the on-going de-control of important generation assets. As a result, a new potential power reactor licensee has appeared, in the form of Bruce Power, a Canadian company but one that has British Energy as the major shareholder.

British Energy is a private (as opposed to Canadian government owned) company, and is based abroad. So we have a new and, particularly for the Canadian Nuclear Safety Commission (CNSC), an unknown player on the scene.

In the same period, the Canadian Nuclear Safety and Control Act has come into force, imposing expanded and more specific requirements on both licensees and the regulator. The full impact of these requirements has still to be felt either by the industry or the CNSC.

The Independent Integrated Performance Assessment (IIPA), Ontario Hydro's independent review of its nuclear operations in 1997, and its aftermath, have not gone away. Two large stations remain shut down - Pickering "A" and Bruce "A". The planned restart of Pickering "A" is clearly tied into the economics of the open market. Post - IIPA, the regulator itself has come under increasing government and public scrutiny.

Finally, all this is going on at a time when attention is being drawn world-wide to issues of nuclear safety infrastructure, research and succession planning. By infrastructure, I mean the combination of human and material resources that are not owned by the utilities, but still are needed to keep the industry safe in the longer term. Research labs, training and education courses and facilities, and specialist expertise all fall under this umbrella term.

So, the impact of the open market, from the CNSC perspective, is complicated by several other significant factors.

### The Opening of the Ontario Market;

The opening of the electricity market in Ontario will be a first for Canadian nuclear power utilities, which to date have enjoyed a virtual monopoly situation. At a relatively simple level of the mechanics of market operation, there are some technical issues relating to CANDU load following and grid reliability assumptions in the safety analysis.

On a more profound level, there are questions of what increasing competition will do for nuclear safety. Nuclear stations provide base load and could benefit financially from an open market where there is not much excess capacity. However, that may not prove to be the case, and there will be shareholders to satisfy. Clearly, there have been budget controls in the past, but now there is the potential of tighter fiscal restraint in the light of new business realities.

One hears that competition makes better operators, and that the financially successful plants are usually the safest. However, from a regulator's point of view, financial competition must be of concern, in that there may be more economic pressure on the operator. These could be pressures to remain operating when the electricity price is high , when it might be prudent to shut down, or to reduce spending on things that do not contribute to the short term bottom line - matters such as training, research, and maintenance. On the issue of maintenance, I would remind you of the sacrifice of long term maintenance on the altar of CANDU production in the early 1980s, something I do not believe any of us want to see again.

The CNSC looks at the open market from a neutral point of view. It has the potential for both good and bad in terms of nuclear safety. In the United States, the Nuclear Regulatory Commission (NRC) tells us that it has not seen any indication of declining safety performance as a result of competition, which is mainly in the North East states and California. However, there has apparently been increasing reluctance of utilities to share information and experience without financial compensation. On the other hand, there are signs that market forces are driving those companies that have elected to stay in nuclear generation in the US to combine into organizations with greater technical depth and resources. This is the opposite of what is occurring in Ontario.

In Europe there are disturbing indicators of the down side of competition. Some nuclear plants are trying to operate when their generating costs are higher than the prevailing market price. In at least one case, this has resulted in a drive to radically extend fuel burn-up times, reduce staff and shorten outages. Two years ago, the Nuclear Installations Inspectorate (NII) in the UK criticised British Energy for letting its core competence fall to a level that could, in the view of the regulator , compromise the licensee's ability to recognise safety problems and to assess contractor's advice.

What does all this mean to Canada? It means that the CNSC, and the industry itself, will need to be particularly vigilant to see that competition does not compromise safety. This is particularly the case in a non-prescriptive regulatory environment, because currently, there are not many specific requirements here, such as the USNRC maintenance rule, to keep the short-sighted operator on track.

## A New Player in the Game

Let me now turn to the issue of a new licensee in the regulatory firmament, arising from the open market and moves to increase competition. The application from Bruce Power to operate the Bruce reactors is the first new power reactor licence application -

- from a private company
- from a foreign (at least in terms of principal shareholders) company
- for a lease arrangement
- for many years (Darlington was first licenced in 1989)

In various forms, the AECB/CNSC has seen applications for other facility licences (eg COGEMA applying for uranium mine licences; MDS Nordion/AECL involvement in MAPLE) that encompass some of these features, but never all of them together and never for a power reactor.

For obvious reasons I don't want to discuss the details of Bruce Power's application when the Commission is in the process of holding a hearing on it. However, there are some general considerations that I can discuss.

One interesting thing is that, in the past, we have had the situation of an existing licensee, eg Ontario Hydro, and a new plant, e.g., Darlington. This time, we have the reverse of that scenario; an existing plant, Bruce, that is known to us, and a new licensee, that is not. Hence our focus in this situation is more on the potential licensee, its management, competence, resources, organization and intentions, rather than on the state of the plant, with which we are reasonably familiar. The CNSC recognizes that the presence of Bruce Power in the Canadian nuclear power scene has potential advantages., not least of which is the ability to bring new ideas into CANDU operations and to call on expertise not normally available in Canada.

## The New Act

This focus is reinforced by the Canadian Nuclear Safety and Control Act (NSCA), another of the interlinked factors mentioned at the beginning. The NSCA states categorically (and I paraphrase) that no licence may be given unless the Commission is satisfied that the applicant is qualified and will make adequate provision for the environment, health and safety of persons, security and the international obligations to which Canada is a signatory.

This requirement places a clear obligation on the CNSC staff to review issues of competence and resources (make adequate provision for...). If we are to be explicit in advising the Commission on these matters, then we will need to have more standards by which to judge them and the industry will need to know what they are, so that they are not caught by surprise. In the United States we see the forces of competition causing the industry to bring political pressure on the NRC to reduce prescription. Here, I perceive the likelihood that the industry will, and does, want more prescription in the interests of business certainty. In any case, implementation of the new act and associated regulations will demand it because there is now a legal onus on the CNSC to make specific judgement. In addition, if industry does not want to pay greater licence fees, the CNSC staff must do more with the same resources. This leads to risk management and determining how much is enough, and hence to documented criteria

## The Independent Integrated Performance Assessment

The IIPA was not in any way related to the open market issue, but I would be remiss not to mention that it has coloured the way in which the CNSC conducts itself. The CNSC was criticized in the aftermath of IIPA for not being more demonstrably pro-active in addressing known industry weaknesses. I spoke in 1999 about our new approach to licensing assessment. You will find now that the CNSC staff reports to the Commission are becoming more detailed, more critical and more and more reviewed by the media and the public.

One thing we learned from the IIPA was that at least some Canadian utility boards of directors may not, in the past, have recognized their responsibility for nuclear safety nor exercised a proper oversight role in this respect. Included in our current review of power reactor management is the issue of "due diligence" by the ultimate financial authority, the parent company's board of directors. This is an example of how we are moving increasingly into non-technical areas in response to the combination of pressures and changing industry circumstances

## Infrastructure, Research and Succession Planning

The activity of reviewing competence encompasses the last factor from my introduction; infrastructure, research and succession planning , which includes knowledge retention. Of particular concern to the regulator is the erosion of CANDU nuclear safety knowledge. This is happening through natural attrition and through decline in resources for research, both from the industry and government. At the same time universities are not attracting students to courses in nuclear science or technology. This isn't news, but it is happening, within my own organization as well, and I am not yet sure that effective steps are being taken to combat it.

## Regulatory Response

What new regulatory approaches are likely?

You are likely to see more prescription; in response: to industry demand for more business certainty, to public pressure to know what standards are being applied, and, to our own uncertainty about the new circumstances that we find ourselves in. Indeed, you are already seeing it in the form of the much more detailed regulations, and an increasing number of regulatory documents emerging from the CNSC. Such documents not only address the new reality of nuclear regulation, they also help to codify our regulatory knowledge at a time when succession is as real an issue for the CNSC as it is for anyone else.

You will also find us moving into new areas as we come to grips with the requirements of the Nuclear Safety and Control Act. These include: the environment, where our involvement is much more clearly defined than hitherto; management issues in general, and, some financial matters, both related to de-commissioning and to operation in order to deal with the " will make adequate provision" clause.

One related area of regulatory focus is the question of design authority. We have sought, and obtained, industry agreement on the definition of this term. You can expect that we will be also seeking definition of a minimum level of competence. This is a difficult issue, but clearly related to the one that the NII raised in the UK and to the likely division of scarce technical resources between Ontario Power Generation (OPG) and its potential competitor, Bruce Power. In our view, this is a matter of considerable importance. It would have arisen anyway, but has been brought to a head by circumstances related to increased competition and the open market.

We are also engaging the industry on the issues related to succession planning and knowledge retention. Dr. Bishop, the past CNSC president held meetings with the senior management of nuclear utilities. AECL and COG were present at the last one. The object of these meetings was to try to maintain momentum and some level of unified action in this area.

Power reactor life extension may prove to be the way to retain design competence and nuclear safety expertise in Canada. Commercial forces in the United States have prompted an extensive drive to life extension that may help maintain nuclear expertise until new generations of reactor designs emerge. There is a parallel interest in life extension in Canada, as evidenced by the re-furbishment of Pickering A and studies of life extension at Point Lepreau and Gentilly II.

I have tried to indicate that there are numerous, interleaved factors that influence our view of the open market development and to take a very brief look at what some of these are. To paraphrase a famous countryman of mine, the winds of nuclear change are blowing through Canada. It is up to all of us to see that they are not 'ill winds' in terms of nuclear safety.

# Heavy Water:

## - a Guide for the Hydrogen Century

*by Alistair Miller*[1]

Once the third most ubiquitous substance in the Universe, to most people deuterium is either unknown or an arcane curiosity. But, as heavy water, it has a crucial role in the CANDU reactor concept. As an isotope of hydrogen, its separation from normal hydrogen is surprisingly easy but its extremely low natural abundance makes such separation relatively expensive. Accordingly, Atomic Energy of Canada Limited (AECL) has worked extensively over the last 40 years on the development of the industrial processes with affordable economic characteristics. Three groups of processes attracted significant efforts and produced technically gratifying results. The most recent effort has brought a family of processes based on water-hydrogen exchange to industrial demonstration. They create potential synergies with industrial production of hydrogen, which many expect will become a major component of the energy systems of the 21st Century.

### In the Beginning

Deuterium provides part of the evidence on conditions at the Big Bang origin of the Universe. Only three simple substances are believed to have formed as atomic matter coalesced out of the primordial plasma: light hydrogen (or protium, to distinguish the common hydrogen isotope) constituted about 75% and the balance was almost all helium. A mere 0.0013% emerged as deuterium, the heavier and stable isotope of hydrogen[2]. Unlike all heavier elements and isotopes, the Universe's supply of both hydrogen and deuterium appeared once and for all. The stellar processes that create everything else are built from the hydrogen isotopes. But while a protium atom has relatively small risk of undergoing fusion inside a star, deuterium is completely consumed within seconds, a testament to its utility as a fuel for fusion.

Now stars are not a major component of the Universe's mass and so have made little inroads on the deuterium content of the Universe since then but interesting local variations have developed. Small rocky planets like Earth have lost hydrogen to space rather prolifically. By preferentially retaining the heavier isotope, deuterium has become enriched to around 0.0155% in Earth?s oceans. (As much drier planets, Mars has attained almost 0.1% and Venus a spectacular 2.2% of the heavier isotope.)

### Who cares?

So deuterium is a minor component of all the hydrogen in us and around us. It is apparently harmless, varying gently in surface water from 0.0130% in arctic surface water to 0.0162% in the Nile in Egypt – the latter, an effect of naturally occurring fractional distillation. Why should anyone want to extract it? In small amounts, it is useful as a tracer of chemical and biochemical reactions and as a protium-free substance for magnetic resonance imaging. The dominant use, however, arises from its properties as a neutron moderator.

Nuclear reactors depend on a chain reaction in which neutrons from an initial fission induce at least one further fission. At the high velocity with which they emerge from fission, neutrons are far less likely to produce a new fission event than if they are first slowed to much lower speeds, the process call moderation. This process is essential for the design and operation of "thermal" nuclear reactors, which predominate in today's nuclear power plants. For the number of collisions needed to slow neutrons from "fast" to "thermal" speeds, protium is unbeatable. In that respect, protium in the form of normal ("light") water is the best moderator and is the reason that light-water reactors have relatively small moderator volumes. (The oxygen in water is, conveniently, invisible to neutrons.) Protium, however, also absorbs neutrons with the result that a chain reaction can only be sustained if the uranium fuel is enriched in fissile nuclei (usually U-235) by around a factor of four above U-235's natural 0.7% abundance. Deuterium, though requiring more collisions and hence a larger volume of moderator, slows neutrons with a much lower risk of capture. Minimal capture means that natural uranium can fuel a reactor moderated with deuterium in the form of heavy water[3]. So designers of thermal reactors have a fundamen-

1 Atomic Energy of Canada Limited, Chalk River Laboratories

2 Protium has an atomic mass of 1. Deuterium adds a neutron to the single proton of hydrogen nuclei and so has a mass of 2. Tritium, the third isotope, has two neutrons, hence atomic mass 3 and is unstable, decaying to helium-3 with a 12.3-year half-life.

tal choice: either, isotopically enrich the uranium fuel in fissile atoms; or, isotopically enrich the moderator in deuterium. The first option is an ongoing requirement. The second, which is the choice of the CANDU is close to being a one-time operation since only around 0.5%/a of the heavy water is lost from a CANDU.

## How best to separate heavy water?

While it is merely an isotope of hydrogen, separation of deuterium from protium is easy compared to some separations of different elements. Both physical and chemical processes abound where the two isotopes behave distinctively. Indeed, considering the great natural dilution of deuterium (below one part in 6000), the ease with which it can be extracted is reflected in a price of only around 300 $/kg $D_2O$. By way of comparison, from a typical natural abundance of around one-sixth that of deuterium in protium, gold extracted from rock costs over 6000 $/kg to extract.

To provide some perspective on the factors affecting the economics of D2O production processes, consider fractional distillation of water. This is the simplest deuterium separation process. At 13 kPa (51°C), the vapour pressure of the deuterated form of water is reduced by 5.5% compared to undeuterated water. Or, to introduce the concept of the separation factor, $\alpha$:

a = deuterium concentration in liquid ÷ deuterium concentration in vapour = 1.055

$\alpha$ is a function of temperature, falling as temperature rises. Because it is only 1.015 at the normal boiling point of water, use of distillation under vacuum is very attractive. **Figure 1** illustrates the simplicity of this process. Water is boiled and condensed at opposite ends of a contacting tower, which is filled with a highly wettable packing, usually made of phosphor bronze. Throughout the contacting tower, liquid and vapour are brought into repeated contact. The falling liquid water becomes steadily enriched in deuterium while the rising vapour becomes steadily depleted. Though the separation factor is quite small, repeated contact amplifies the effect. It is common for such a system to have the equivalent of some hundreds of equilibrium contacts – i.e. increments of packing in which the exiting liquid and vapour are in equilibrium with each other.

The process could hardly be simpler. Heat is applied at the bottom; cooling at the top. There are no moving parts and it is almost totally sealed. The only adjunct processes required are a small system to eject any air inleakage and good purification of the water feed to eliminate anything that could corrode or coat the packing.

The limitation of water distillation lies in the quantities of water that must be evaporated. Because the separation factor is relatively small, the internal flows between the boiler and the condenser must be around 13 times larger than the feed flow. This is not a serious problem for small quantities of recovered water but it is huge detraction from the possible use of water distillation for primary production of $D_2O$. For $D_2O$ production, around 100,000 times the product rate would have to be boiled and condensed. The temperature at which this heat of vaporization must be applied is admittedly fairly low but, even if heat were free, the volume of packing to handle immense vapour flows is prohibitively expensive.

Note though that processes that are unsuited to primary $D_2O$ production can be useful for other separations of hydrogen isotopes. Thus, water distillation has been used almost invariably to reprocess the small escapes of $D_2O$ in CANDU reactors that are recovered by dryers because the volumes are low.

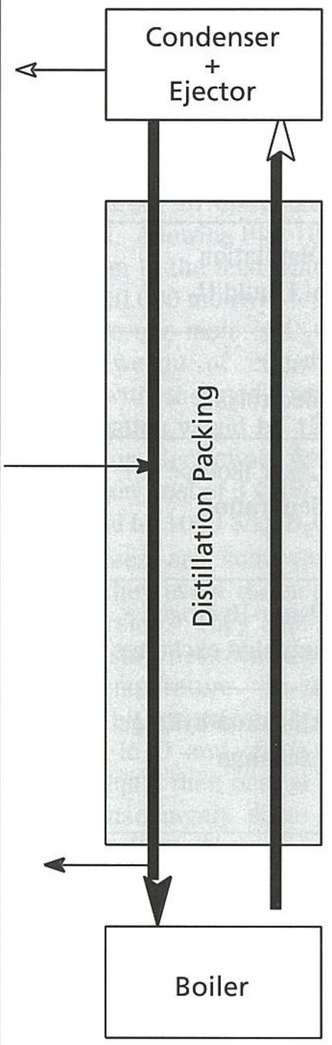


Figure 1:
Fractional distallation

For primary production, vacuum distillation is uncompetitive because: (1) the separation factor is too small, and, (2) the energy requirement too large. This process does however have advantageous features: (1) the exchange rate is fast; (2) a liquid and a vapour are involved and so countercurrent contact is possible; and (3) the feed, water, is available in unlimited amounts.

Those five characteristics provide quite a comprehensive framework to assess the suitability of a physical or chemical process for $D_2O$ production. **Table 1** compares some of the other possible processes for $D_2O$ production against those five criteria. Those that make a process uneconomic are shown in bold. Process strengths are shown in italics.

3 On the rare occasions when neutrons are absorbed by deuterium, two times out of three, an atom of tritium is formed. The third neutron behaves advantageously, fissioning the deuterium nucleus and ejecting a protium atom and two neutrons.

| Process | Separation Factor | Energy Needed | Natural Exchange Rate | Counter-t current Flows | Feed |
|---|---|---|---|---|---|
| Distillation of $H_2O$ | 1.015 to 1.055 | Very high | Moderate | Yes | Water |
| Distillation of Liquid $H_2$ | ~1.5 | Moderate | Slow | Yes | Very pure $H_2$ |
| Water electrolysis | 5 to 10 high | Very | Fast | No | Water |
| Laser Isotope Separation | Huge; Can be > 20,000 | Moderate? | Slow | Unimportant | CFCs |
| Water-Hydrogen sulphide exchange | 1.8 to 2.3 | High | Fast | Yes | Water |
| Ammonia-hydrogen exchange | 2.8 to 6 | Moderate | Slow – catalyst needed | Yes | $H_2$ |
| Aminomethane-hydrogen exchange | 3.5 to 7 | Moderate | Slow – catalyst needed | Yes | $H_2$ |
| Water-hydrogen | 2 to 3.8 | Moderate | Almost non-existent – catalyst needed | Yes | Water |

Table 1: D2O Production Processes Overview

Table 1 contains a wide range of process types, all capable of producing D2O, but reveals no economically outstanding process. Each process has strong and weak points.

Water electrolysis has a high separation factor but the only way to apply it repeatedly is to recombine the oxygen and hydrogen and then repeat the electrolysis, which is very energy intensive. (Strictly speaking, electrolysis depends not on equilibrium but on a kinetic isotope effect in which H is evolved much faster than D. While the separation factors for the other processes are precise thermodynamic values and functions of temperature, the rate-determined ones for electrolysis and laser isotope separation depend on details of the equipment.)

Laser isotope separation (LIS) offers tantalizing possibilities. **Figure 2** illustrates the concept, which is based on the different resonant frequencies of bonds ending in a protium and deuterium atom. In theory, one could tune a laser to the exact frequency of a deuterated bond, break it, and so free deuterium with exquisite selectivity. However, rupturing a chemical bond with a single photon requires UV energies and those are not available with reasonable energy efficiency or cost.

This impasse was circumvented by the discovery by Marling[1] at Lawrence Livermore Laboratories that a cascade of infared (IR) photons could be just as selective if the photons were tuned to the first transition above the electronic ground state. Extensive follow-up by AECL at Chalk River confirmed the principle and revealed its limitations.

The simple molecules that are available industrially on a sufficient scale – water, hydrogen, ammonia and methane – are not susceptible to this process. So an intermediate transfer step would be required for a practical process, the photo-selective molecule being re-deuterated by contact with water. Even with perfect selectivity, one photo-selective molecule would be destroyed for every atom of D released. So most chemicals could be eliminated as simply more expensive atom-for-atom compared to D. Any losses of undeuterated molecules would further curtail the price range of suitable working molecules. The photo-selective substance has to be amenable to a countercurrent re-deuteration process, either as a gas or a liquid virtually immiscible with water and yet capable of exchanging D and H atoms with water. (The alternative of contact of a liquid with steam would use excessive amounts of energy.) All these things considered, the most interesting molecules were found to be cholorofluorocarbons. Separation factors up to 26,000 were measured. Unfortunately, quite apart from chlorofluorocarbons being excoriated for their damage to the Earth?s ozone layer, review of the exchange step to replenish the D content of the active molecule placed this process somewhere between impracticable and uneconomic.

For any extraction process, the initial step, which treats the entire deuterium-carrying feedstock, must be simple. But the LIS approach to deuterium extraction illustrates that simplicity in itself is not necessarily sufficient. Countercurrent contact between water and the working molecule is simple enough but would have to sit precariously between easy transfer of H and D without substitution of -OH for -H or significant losses of the working molecule to solution in the effluent water. Assuming the working molecule was gaseous – rates of exchange for gas-liquid contact are usually faster than those for liquid-liquid exchange – this step would benefit from high pressure but the laser dissociation step needs low pressure so flow of the working molecule that is at least as large as the water feed would need to be compressed and expanded.

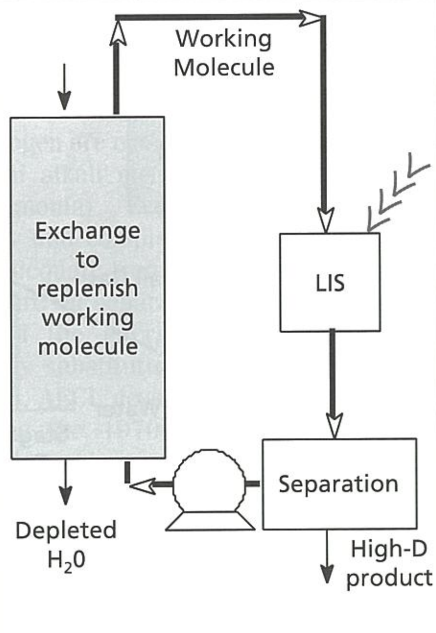


Figure 2: Laser isotope separation

## Processes Based on Chemical Exchange

The remaining processes in Table 1 all depend on the separation factors between two chemical species influencing a reaction of the type:

$$HX + DY \longleftrightarrow DX + HY$$

## Monothermal versus Bithermal Processes

One species is a gas, the other a liquid. Quite large separation factors exist for the pairs of chemical species listed and they can be exploited in two approaches: monothermal and bithermal processes. These are illustrated in **Figures 3A and 3B.**

Monothermal processes are very simple. Equilibrium favours deuterium in the liquid species. So, by converting the liquid into the gas, the gas can then be used to enrich the incoming liquid in D. The effect can be amplified by countercurrent flow of the liquid, prior to its conversion, with the gas, after conversion. Quite short exchange columns can achieve high deuterium enrichments because the gas enters the exchange column at the same concentration as the liquid leaving it and so is far removed from equilibrium. Note too that a substantial part of the deuterium in the liquid can be extracted since the D concentration in the gas leaving can be as low as $1/\alpha$ of the feed concentration.

There is only one problem with monothermal processes: a simple conversion process has to exist and it has to be very low cost since it will have to treat the entire feed flow. For two of the four processes in Table 1, there is no practicable conversion process. However, both water and ammonia can be converted into hydrogen. Ammonia is comparatively easy to dissociate thermally, requiring 45 kJ/mol. Plants using this monothermal process have been built in India and Argentina.

Water is much harder to dissociate, requiring 240 kJ/mol. Allowing that 100 ppm of the deuterium in the feed water could be extracted, 10,000 moles of feed water would produce one mole of $D_2O$. With a molecular weight of 20, the energy associated with thermodynamically perfect dissociation would be 120 GJ/kg $D_2O$. So, using electrolysis with electricity at a very low cost of 3 ¢/kW.h, the energy cost would be 1000 \$/kg $D_2O$.

Bithermal processes are somewhat more complex but they avoid the need for chemical conversion. They exploit the inverse relationship between separation factor and temperature. So the cold tower of a bithermal process enriches the liquid in D and strips D from the gas. The liquid then passes to the hot tower where $\alpha$ is smaller. Consequently, some of the deuterium in the liquid is forced back into the gas and the hot tower progressively depletes the liquid and enriches the gas in D. Where liquid is the feedstock, the gas is

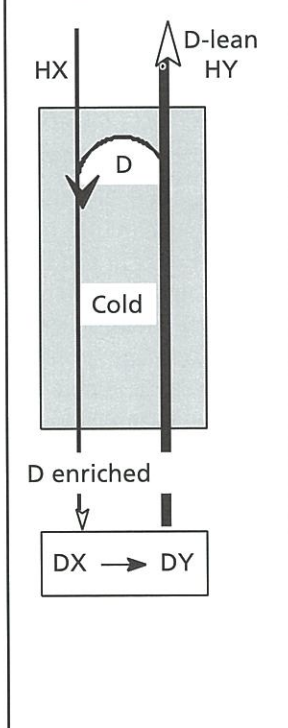


Figure 3A: Monothermal process

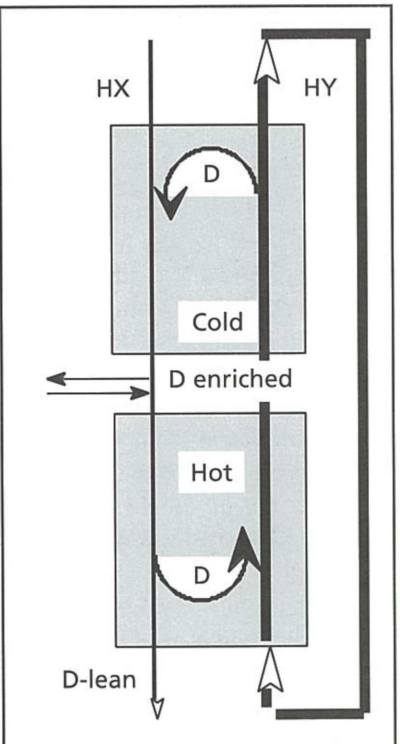


Figure 3B: Bithermal process

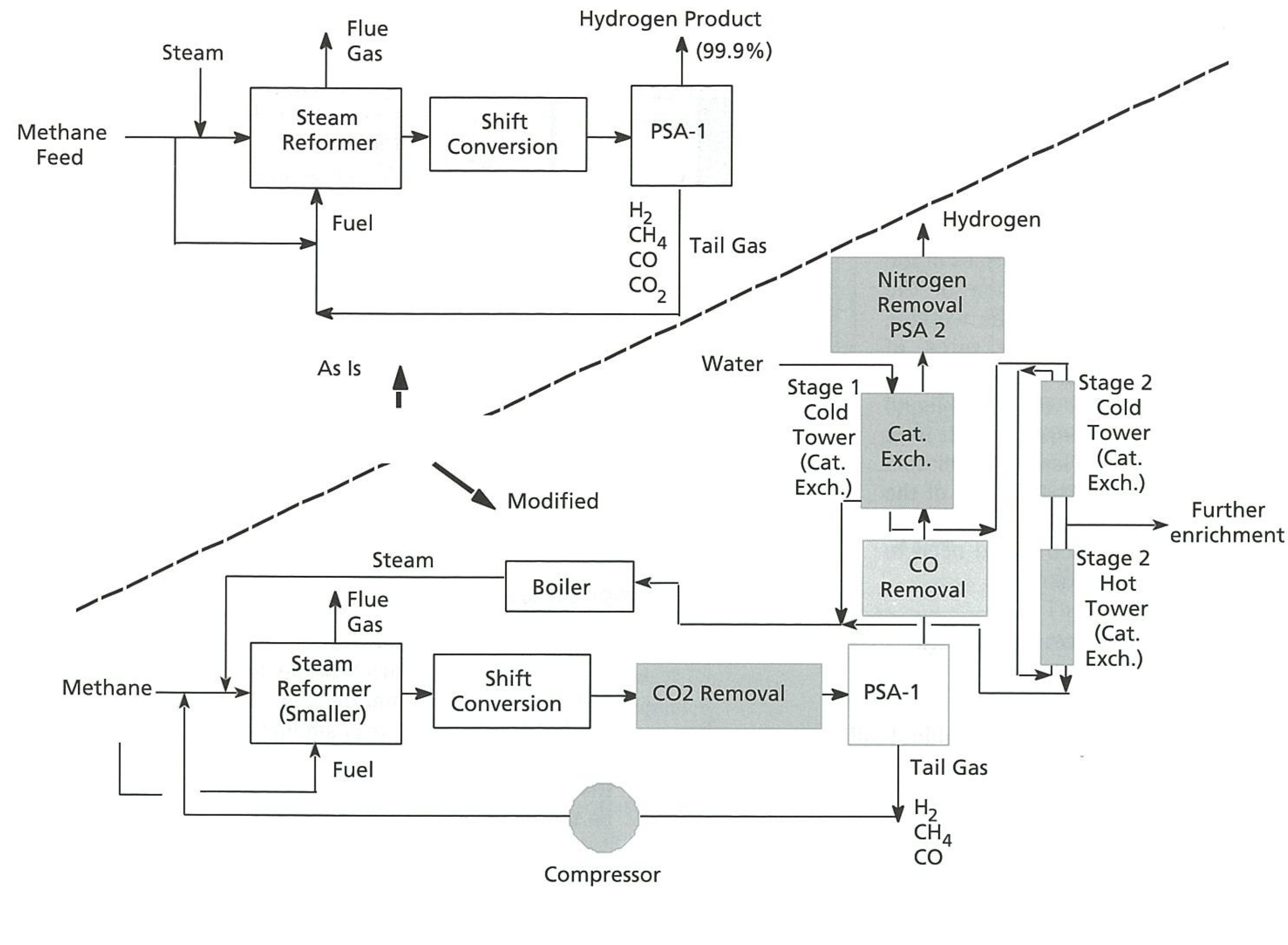



Figure 4: CIRCE process

recycled. (This is usually the case but gas-fed bithermal processes are just as feasible.) Note that extraction of D from the feedstock is limited by the ratios of $\alpha$ in the hot, $\alpha_h$, and cold, $\alpha_c$, conditions. The maximum extraction is ($1 - \alpha_h / \alpha_c$ much less than the ($1 - \alpha_c$) of the monothermal process. Further, not only is a hot exchange column needed, but the cold exchange column is lengthened too because the gas concentration entering it is much lower than occurs with the monothermal process.

## Which Chemical Pair?

The four pairs listed in Table 1 have emerged as the options of choice. None is ideal.

## Girdler-sulphide

The water-$H_2S$ combination is the basis of the bithermal Girdler-Sulphide (G-S) process. This process has produced far more heavy water than any other in Canada and world-wide. The G-S process had not been easy to deploy and AECL and Ontario Hydro put much effort into mastering it: problems with foaming were overcome with the development of antifoaming agents to add to the feed water; corrosion and erosion occurred and were overcome by choice of materials and control of process conditions; the reasons for poor contact efficiency between the gas and the water were explored and improved; and the process was modelled in great detail, allowing more effective operation. As a result, by around 1980, four Canadian plants were operating very successfully, producing over 2000 tonnes of $D_2O$ a year and glutting a fading market for new reactors with their output. Three plants were quickly taken out of service and the last half of the fourth plant ceased operation in 1997.

The G-S process was a triumph of engineering stubbornness: it uses large amounts of steam energy (>10 Mg/kg $D_2O$); $H_2S$ is highly toxic and corrosive; and the separation factor does not vary greatly over the rather narrow range of temperatures than can be used. The only upside for the G-S process is that the exchange reaction is fast and occurs without a catalyst.

## Ammonia-hydrogen and aminomethane-hydrogen

The other three pairs all need catalyst assistance. Ammonia-hydrogen and aminomethane-hydrogen are closely related and both depend on ammoniacal alkali metal salts to catalyse the reaction ($KNH_2$ in ammonia). Even with these, the reaction is still rather slow and complex mechanical agitation is needed to provide adequate transfer rates. To exploit the effect of temperature on separation factors, refrigeration is needed and the energy demands of the process are significant. By substituting aminomethane ($CH_3NH_2$) for ammonia ($NH_3$), AECL developed a superior bithermal process during the 1970s. Aminomethane has faster kinetics and a rather wider temperature range. An industrial prototype of this process was about to be committed in 1979 when the demand for $D_2O$ suddenly turned down.

Both monothermal and bithermal ammonia plants have been built and successfully operated. Some depend on hydrogen plants for their feedstock and some on water-ammonia exchange to replenish the deuterium content of the ammonia. Though less hazardous than $H_2S$, ammonia and aminomethane are both toxic.

## Water Hydrogen

How much simpler it would be if one could use the water-hydrogen pair. As Table 1 indicates, water and hydrogen do not, however, exchange hydrogen isotopes without a catalyst and a good catalyst is the key to applying this system. That requirement apart, this pair has many attractive features: it operates in a moderate temperature range; there are no toxicity or corrosion issues; and both substances are available as feedstocks on a large scale. Water-hydrogen exchange was, in fact, applied to produce up to 6 tonnes/a of $D_2O$ in Trail, B.C., between 1944 and 1956. However, the catalyst undermined its economics.

Water and hydrogen will exchange hydrogen isotopes in the presence of various metal catalysts. Platinum has long been recognized as the most effective metal for this purpose. However, because of the low solubility of $H_2$ in water, even a thin film of water reduces catalyst activity to near zero. To get round this impasse, the Trail plant used a succession of co-current contacts between hydrogen and superheated steam, each contacted separated by a condenser and a boiler/superheater. There was thus no natural countercurrency in the process and it was hugely energy-intensive.

Development of a "wetproofed" catalyst by AECL has been the key to processes based on water-hydrogen exchange. The idea is very simple: apply a film to the catalyst surface that is water-repellent but will permit ready passage of water vapour and hydrogen. In practice, developing really effective catalysts with high activity and long life has been a major undertaking spanning over three decades. However, AECL now has effective catalysts and continues to enhance their performance.

## Monothermal water-hydrogen

If electrolytic hydrogen were being produced on a large scale (>_100_MW), the addition of a monothermal water-$H_2$ process to produce heavy water would produce $D_2O$ at an unbeatable price. This process is known as Combined Electrolysis and Catalytic Exchange (CECE). Alas, while electrolysis is widely used to produce hydrogen of high purity in small quantities, large-scale production by electrolysis has been very unusual. (See, however, below.) Large-scale production of hydrogen is preponderantly produced by steam-methane reforming (SMR), whose basis is the reaction:

$$CH_4 + 2H_2O \longrightarrow 4H_2 + CO_2$$

Here again, water is converted into hydrogen. So there is again the possibility of a monothermal process, which we refer to as the Combined Industrial Reforming and Catalytic Exchange (CIRCE). This is illustrated in **Figure 4.** Obviously, it is much more complex than CECE. It is also more demanding in a number of ways: (1) the water flow is half that of the hydrogen, which means that the two species come closer to equilibrium in transferring deuterium into the liquid; (2) the whole SMR must be a tightly closed system to contain material enriched in deuterium by a factor of 10 to 20; and (3) traces of carbon monoxide normally present in SMR-hydrogen must be eliminated since

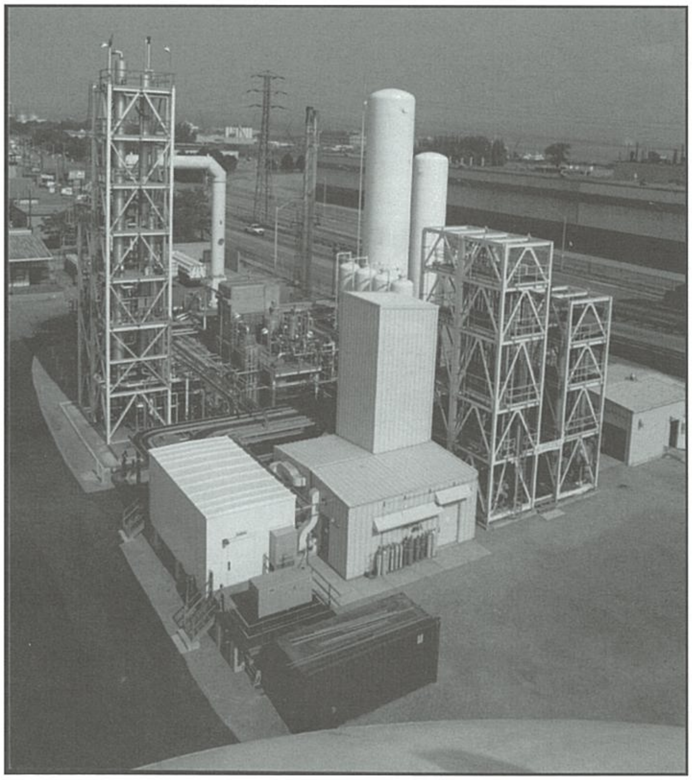


Figure 5: Prototype SMR plant

CO poisons the exchange catalyst. These are all tractable issues, demonstrably so with the successful operation of a prototype plant by AECL at a small SMR in Hamilton, owned by Air Liquide Canada **(Figure 5).**

The prototype is a comprehensive demonstration of the technology: beside the CIRCE first stage, it incorporates a bithermal water-hydrogen second stage (producing 10% D) and a CECE third stage to complete the enrichment to reactor-grade (99.72 mole%) $D_2O$.

Another prototype plant at AECL's Chalk River Laboratories has recently completed qualification of the CECE process for use as a heavy-water upgrader (at around half the cost of water distillation) and for tritium removal from heavy water.

## Where Next?

By mid-2002, the prototype CIRCE plant at Hamilton should have completed the demonstration of this process for heavy-water production. Large SMR plants are ubiquitous. Successful operation of the prototype plant, taken together with ongoing work to lower the cost of the exchange catalyst, will provide the anchor process for future $D_2O$ production. However, the CECE process would always be better if only electrolysis were used for large-scale production of $H_2$.

Now $H_2$ is much touted as *the* fuel for the new century. Burned in fuel cells, it is free from the polluting effects of VOCs and NOx. If it were produced electrolytically from electricity produced by nuclear or other low-$CO_2$-releasing sustainable technologies, it could be the ultimate transportation fuel source to redress greenhouse gas emissions associated with traditional fuels or hydrogen produced by SMR technology. The combination of nuclear electric generation — water electrolysis — and $D_2O$ production by CECE is an alluring possibility.

1 Marling, J.B., Herman, I.P., and Thomas, S.J., J. Chem. Phys., 72, 5603, 1980.

*A view of the Bruce heavy water plants in 1992, before dismantling.*

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# Auditor General reports on CNSC

## - and the CNSC responds

***Ed Note:** In early February 2001 the federal Auditor General issued his report for the year 2000. Included was a chapter on the Canadian Nuclear Safety Commission, with emphasis on the regulation of power reactors. Following is an excerpt from that report including the CNSC responses, combined with relevant sections of the CNSC's "Action Plan" issued later that month. The Auditor General's reports are available on the Web site: www.oag-bvg.gc.ca.*

### Objectives

Our objectives for the audit were to:

- assess whether the regulatory regime for power reactors has been satisfactorily designed , structured, organized and implemented to achieve its safety and other objectives, for example, cost recovery; and,
- identify factors or constraints that affect the development or implementation of regulatory regimes. These may include delays in legislative changes, overlaps with provincial jurisdictions, downsizing, and the effects of international harmonization of regulatory approaches.

### Scope and Approach

We conducted structured interviews with 88 people, including senior executives in CNSC and industry. We visited three licensees at four plant sites and also visited the Nuclear Installations Inspectorate in the United Kingdom. In addition, we reviewed more than 250 documents. Our audit was conducted between October 1999 and July 2000.

### Focus of the audit

Our audit focussed on the regulatory activities related to the licensing and regulation of power reactors. This area of the nuclear industry is the most complex to license and regulate and the one undergoing the greatest change. In Ontario, major changes are expected from deregulation, the introduction of competition in 2000, and private investment. The CNSC's responsibilities related to power reactor licensees account for approximately half of its costs. In fiscal year 2000, CNSC had 440 staff and its total costs were $59 million. Power reactors represent the CNSC's most significant responsibility, given the risks to public health and safety in the event of a major accident. In addition, certain power reactor operators acknowledged in the mid-1990s certain difficulties with the management of their stations and operating units. (See photograph)

Our objectives in this audit were to examine whether the regulatory regime for power reactors was satisfactory to achieve its safety objectives and others. We also sought to identify factors or constraints that affect the development or implementation of regulatory regimes.

### Observations and Recommendations

#### Risk Analysis and Performance Assessment

**A need to improve risk analysis and assessment of licensee performance**

We expected that the CNSC would base its regulatory activities on an analysis of relevant risks, the results of previous regulatory activities, and a rigorous, well-documented process linking activities to required results. We expected that it would report its assessments of regulatory performance in a way that was clear and understandable to all stakeholders.

The CNSC does not use quantitative measures to rate nuclear power facilities. It is aware that the industry is making extensive use of nuclear power plant performance measures, including safety-related indicators, and it is testing and refining its own recently developed set of safety performance indicators. CNSC divisions involved in power reactor regulatory work have used an intuitive approach, relying on the judgment and expertise of staff. However, safety performance indicators along with that judgment and expertise are not yet applied in any systematic, integrated way. Without this type of analysis, CNSC cannot demonstrate whether it is doing enough work in any area or too much, and whether it is overstaffed or understaffed.

In its licensing reports, the CNSC assesses and categorizes various aspects of performance as "acceptable", "conditionally acceptable", or "unacceptable". In addition, it provides an overall qualitative assessment of the licensee's performance along with a recommendation on whether the licence should be renewed. The rating "conditionally acceptable" does not clarify whether and to what degree safety is being managed properly and the licensee's action plans and progress are satisfactory.

**[Recommendation] The Canadian Nuclear Safety Commission (CNSC) should implement a quantifiable rating of safety performance, taking into account the safety-related portion of other systems used in the industry, and should use this rating, along with a more rigorous and integrated risk assessment and other qualitative information, to systematically determine the level and type of regulatory effort required.**

***CNSC's response:*** *The CNSC undertakes the regulation of safety performance by committing to a comprehensive program of regulatory oversight activities. The CNSC agrees that quantifiable ratings of licensee performance could, as part of an integrated risk assessment process, support the determination of priorities, and the level and type of regulatory effort that is deployed for different regulatory activities. The CNSC will evaluate options for such approaches.*

*CNSC Action Plan*

*The CNSC has exercised effective regulatory oversight of its licensees for many years. However, regulatory principles demand the use of a systematic and transparent system of resource allocation and that such a system should be risk based. Over the last few years, the CNSC's planning and budgeting processes have been improved and by 2003, they will be more closely integrated, with resource allocation based on risk. To further improve our resource allocation, the CNSC has initiated a pilot project for systematic management of regulatory effort that includes priority setting, risk management, and focusing on achieving results. By 2003, the experience gained from that pilot project will be used to establish a systematic corporate approach to resource allocation. We are also evaluating management reporting systems that will provide CNSC management with planning and accountability information more efficiently and effectively.*

*As part of an improved reporting of safety, we will consider the use of quantifiable safety ratings in the overall risk assessment. By early 2002, we will have completed a review of work being done by other nuclear regulators to establish quantitative indicators of safe operation of nuclear power plants, and we will also seek improvements in the clarity and utility of the qualitative indicators that are being currently being used. We will use this information to ensure that the overall performance of each licensee is clearly communicated; that the specific licensing plans for each reactor facility clearly reflect priority areas of regulatory oversight, and to improve the CNSC's annual reports on overall safety performance of the nuclear power reactor industry in Canada.*

**[Further Recommendation by AG] CNSC should also clarify the meaning of its performance ratings ("acceptable", "conditionally acceptable" and "unacceptable") and better integrate its findings to ensure that a licensee's overall performance is clearly understood and communicated.**

***CNSC response:*** *The CNSC agrees that rankings of "acceptable", "conditionally acceptable", and "unacceptable" need to be clarified to enable consistent application and effective communication of licensees' overall safety performance. A review of the use of these rankings has already been initiated with a target for completion by fall 2000.*

*CNSC Action Plan*

*The review of the CNSC's current approach to communicating its rating of safety performance is intended to produce clearer and more objective terminology that reflects the overall safety perspective and is therefore more useful in decision-making and more understandable by all stakeholders. It is anticipated that an improved rating system will be presented to the Commission by August 2001 and will be in use by the end of 2001.*

## Compliance and Enforcement Framework

### Development of the compliance and enforcement framework has not been completed

After Parliament passed the Nuclear Safety and Control Act in 1997, the CNSC made considerable progress in revising some regulatory documents and developing new regulations that would be needed when the Act came into force. However, management acknowledged that uncertainty as to when this would happen contributed to delays in completing other regulatory documents. Now that the Act is in effect, regulatory documents such as standards, policies and guides are needed to clearly explain the CNSC's regulatory requirements to staff, licensees and the public. Eight major regulatory documents that set out regulatory expectations for nuclear power plants have been carried over from the old regime, but the CNSC has determined that it needs about 50 more documents for licensees as well as important additional guidance for staff.

Both managers at the licensed nuclear facilities and staff of the CNSC, particularly those at site project offices, have asked that the CNSC give high priority to completing regulatory documents and communicate the new expectations clearly, particularly for the compliance program. To make the regulatory system transparent and effective, licensees need a clear understanding of the regulatory requirements, the processes for monitoring compliance, and the rules of enforcement.

**[Recommendation] To ensure that its regulations are transparent and predictable to staff, licensees and the public, the CNSC should, with all due haste, finish developing the regulatory documents that set out the requirements by which licensees will be assessed.**

***CNSC's response:*** *The CNSC agrees that there is a need to accelerate the development of a number of regulatory policies, standards and guides. Specific objectives for this work are set out in the CNSC's Strategic Plan 2000. To achieve ordered progress in this area, senior staff members have been taken off-line and assigned full time to the development of the regulatory framework, and a committee has been set up to establish the priorities for work on regulatory documents.*

***CNSC Action Plan***

*We have made progress in producing regulatory documents setting out the requirements by which licensees will be assessed. These regulatory policies, standards and guides aim to make CNSC regulations and requirements transparent and predictable to staff, licensees and the public. Current regulatory documents as well as those in the consultation stage are available on the CNSC website at www.nuclearsafety.gc.ca. The website also provides a full list of titles and description of regulatory documents which are under development but not yet available for public consultation. All key regulatory policies and standards will be in place and all key regulatory guides will be out for public comment by 2003.*

*The requirement for further development and continued improvement of regulatory documents is fundamental to the regulatory environment. To support this, by March 2001, we will complete a regulatory framework which defines the basic elements of our regulatory regime and the fundamental policies which underpin them. The framework will provide a logical and organized structure which will help us identify and develop regulatory documents consistently and coherently across all areas of regulatory responsibility and set priorities for their production.*

**[Further Recommendation] It [CNSC] should also implement its compliance and enforcement policy.**

***CNSC Response:*** *Among the activities that are already in progress is a comprehensive program that is dedicated to the implementation of the compliance and enforcement policy.*

*CNSC Action Plan*

*Building on the compliance activities carried out by the Atomic Energy Control Board over its long history of regulatory activity, the CNSC Compliance Program introduces a more modern, transparent and predictable way of carrying out our compliance function. The CNSC Compliance Policy was issued for public comment in May 2000; the final version will be published shortly. An overview of the CNSC Compliance Program was also published in May 2000; a program manual for CNSC is now being completed. Implementation of the compliance and enforcement policy and program is now underway in all areas of regulatory responsibility.*

## Human Resource Management

From the early years of the CNSC, the combination of its small size and its growing technological complexity fostered the evolution of an informal organizational structure and related regulatory processes. The CNSC adopted a non-prescriptive approach to regulation, relying on the competence and professional judgment of its growing complement of knowledgeable staff.

As its staff increased from 50 in the early 1970s to about 440 today, the CNSC was successful in attracting suitably qualified scientists and engineers from industry to its expanding organization. However, its approach to regulation continued to be non-prescriptive and relied heavily on the knowledge and competence that its staff had gained earlier in their careers. In the

1990s, it became clear that this pool of expertise would begin to disappear as experienced staff moved closer to retirement eligibility. Given the shrinking pool of external expertise and an increasingly competitive market for talent, it was obvious that the CNSC would need to make major adjustments to the management environment.

## Recruitment and staffing strategies needed

Like other federal regulatory organizations and nuclear regulators in other countries, CNSC faces difficulties in recruiting scientific and technical staff. At May 2000 the organization had 54 vacant positions - 29 in the power reactor business line. Some positions have been vacant for more than a year, and vacancies of 3 to 10 months are common. As an example, during the past year there were seven vacant positions for inspectors. Although the CNSC's recruiting efforts generated 351 applications, the five offers it made were rejected. Five positions have since been filled through redeployment; two remain vacant. In fiscal year 2000 there were 28 new staff hired, and 16 internal moves took place within the power reactor business line.

The CNSC has streamlined its processes, initiated some new recruiting activities, and developed other means to help retain staff, such as policies for retention bonuses and career development and training programs. However, it has not developed a formal recruiting strategy and action plan to give priority and direction to its efforts at filling the technical and other staff vacancies. The present vacancy rate (about 12 percent overall; 8 percent in the power reactor regulation business line) and the lengthy periods of vacancies in technical positions have a significant impact, in our view, on the CNSC's ability to effectively inspect and regulate the nuclear industry, despite management's efforts to reduce that impact. Some key areas are understaffed at a time when the workload is particularly heavy. The lack of staff has contributed to delays in completing plans for relicensing some power reactor plants.

CNSC needs to develop a formal recruitment strategy and action plan to overcome the deficit in staff and ensure that the organization possesses the skills and expertise to fulfil its mandate.

## Succession planning is a priority

The employee population in the CNSC is aging: according to data provided by CNSC, at April 1999 the average age was 45 years, identical to the public sector regulatory/inspection community but higher than the general public service population at 42 years. Also, 31 of 74 managers could choose to retire within the next five years.

Depending on how many retire, the CNSC could face not only loss of leadership but also loss of the high-level expertise that the current group of executive managers and other senior staff have acquired over many years.. Moreover, the potential attrition by retirement at other levels across the organization heightens the need for a formal recruitment strategy and action plan that takes full account of the future staff needs resulting from attrition.

We encourage the CNSC to continue its succession planning efforts and complete its strategy and action plan for recruitment, based on historical and potential attrition rates.

**[Recommendation] The CNSC should develop a human resource planning process that profiles present internal resources and forecasted needs, identifies historical, present and potential attrition rates, and assesses the implications of various policies on the distribution and movement of employees. It should update the human resource plan regularly and link it to the maintenance and administration of a formal plan for recruitment.**

***CNSC's response:*** *The CNSC recognizes that in the past, human resources planning may not have been conducted as rigorously as it should have been. The CNSC agrees with the intent of the recommendation and has already put into place a human resources planning process. The CNSC believes that its Strategic Plan has been very clear on this point, and it will endeavour to strengthen linkages between the strategic, corporate and budget planning processes and the human resources plan.*

*CNSC Action Plan*

*The CNSC will continue to improve its human resources planning, building on the extensive work that has been carried out over the last two years. As is the case with other health and safety regulatory agencies, the CNSC is experiencing staffing shortages due to its inability to meet private sector salaries for the specialized resources it needs to regulate, an aging workforce jeopardizing long term sustainability, and limited funding to aggressively redress these problems rapidly.*

*While these problems are not unique to the CNSC, the issue of a limited pool of qualified recruits is particularly acute in the nuclear field. More specifically, the lack of new nuclear facilities increases the perception of the industry as one with no future. As a result, students do not see a future for themselves in the nuclear industry, and universities no longer offer programs aimed at graduating students specialized in the nuclear field. The lack of a graduate pool, tightly controlled public service salaries, and fierce competition from private sector nuclear employers and agencies render the CNSC's recruitment, rejuvenation, and retention challenges very difficult. Given Canada's commitment under the Nuclear Safety Convention to maintain an adequately resourced nuclear regulator, the CNSC is resorting to an increased effort and resource investment in training as it cannot attract fully qualified specialists in sufficient numbers.*

*During the next two years, the CNSC will focus its efforts on three areas it can influence with its limited resources. First, the CNSC will seek and leverage partnerships with academia and industry to support strengthening of nuclear education programs through a sharing of our knowledge and documentation. Secondly, the CNSC will continue to work with Treasury Board to stabilize its funding at a level commensurate with its responsibilities under the Nuclear Safety and Control Act. Thirdly, the CNSC will continue to establish human resources strategies which promote workforce sustainability through improvements to recruitment, retention, and succession planning.*

*CNSC has already improved vacancy and staffing reporting to executive management, completed demographic analysis of the executive cadre and completed a process for identifying successors for executive level positions. It has also developed and approved a pilot internship program for regulation of power reactors.*

## Roles and accountabilities need to be clarified

Until 1998, the CNSC was structured in such a way that the site project office at each nuclear power reactor site co-ordinated much of the regulatory activity related to planning and conducting evaluations of performance of power reactor facilities. In January 1998, the CNSC initiated changes to improve its planning, integration, and reporting of regulatory activities related to the licencing of power reactors. A new division was formed to manage the review of reactor facility design, construction, operation, and maintenance; integrate the information generated by all relevant CNSC activities; and advise senior management and the members of the Commission on the overall performance of each nuclear facility.

At the time of our audit, the respective roles and accountabilities of the site project offices and the headquarters technical specialists were not clearly defined and understood. For example, the staff at site project offices are unclear on who is responsible for taking the lead on specific issues. Assumption of the lead role is often ad hoc, and various groups play a role in evaluation and assessment. The lack of a clear understanding and effective implementation of the centralized approach to planning and reporting has allowed for the fragmenting of accountabilities and made it difficult to reach consensus on the overall level of safety at each nuclear facility.

The CNSC comprises five members of the Commission, including the President, appointed by the Governor in Council. The President is the chief executive officer and directs the work of both the members of the Commission and CNSC staff. The President chairs meetings of the members of the Commission. Many of the people we interviewed noted that senior management is responsible for developing regulatory philosophy and documents, but has had difficulty dealing with key issues. This has led to long delays in implementing change. Others we interviewed cited a lack of understanding between members of the Commission and CNSC staff on some regulatory issues.

While there is a need to maintain the regulatory independence between the staff and members of the Commission, we believe that clarifying roles and accountabilities by separating the position of chair of the meetings of members of the Commission from that of chief executive officer could improve the efficiency of the CNSC's operations and help it to demonstrate its effectiveness.

**[Recommendation] The CNSC should clarify the roles and accountabilities for planning and integrating regulatory activities and reporting on licensee performance, and communicate them internally and to licensees.**

***CNSC's response:*** *The CNSC agrees that, to improve accountability and regulatory effectiveness, effort is needed to improve the implementation of the roles and responsibilities for planning and integrating regulatory activities and reporting on licensee performance. A review of roles and responsibilities has been planned. It will be followed by action to communicate and manage implementation of the resultant responsibility framework, consideration in addition to other options.*

*CNSC Action Plan*

*We are now reviewing the specific roles and accountabilities of the operational divisions to identify where adjustments can improve assessment of licensee performance. These adjustments will be made and communicated to staff and licensees. To improve regulatory effectiveness and planning, a procedures manual is being developed for use by all CNSC staff involved in nuclear power reactor regulation. It will clarify the roles and responsibilities of those involved in power reactor regulation and the interactions between them. The manual will be used by all power reactor licensing staff in Ottawa and CNSC on-site offices and will also be included in training materials for new staff joining the CNSC.*

**[Further recommendation] In addition, it [CNSC] should consider separating the role of chair from that of chief executive officer.**

***CNSC Response:*** *The separation of chair and CEO is not our preferred solution to some of the issues raised. However, we will take it into consideration in addition to other options.*

*CNSC Action Plan*

*A review of the current responsibilities of the CEO and President was completed for development of the NSC Act. The newly appointed President and CEO took up her duties on January 1, 2001. No changes are currently foreseen*

## [AG] Conclusion

The public places a high reliance on the regulator of nuclear power facilities, and the CNSC is committed to operating in an open and transparent fashion. In our view, if CNSC strengthens its risk analysis and assessment, completes the changes it has begun in compliance and enforcement, and takes steps to ensure that it has the human resource capacity it will need in the future, the regulatory regime for power reactors will be designed, structured, organized and implemented to achieve its safety objective and other objectives.

# CNSC rules on Pickering environmental assessment

On February 16, 2001, the Canadian Nuclear Safety Commission issued its "Record of Proceedings and Reasons for Decisions in the matter of the environmental assessment under the Canadian Environmental Assessment Act of the proposed return to service of the Pickering "A" nuclear generating station. The full report (which includes a record of the meeting and the names of all participants) is available on the CNSC web site < www.cnsc-ccsn.gc.ca >. The following extract is the text of the Commission's "Decisions" and the h "Reasons for Decisons"

### Decisions:

*"The Commission decides that the project, taking into account the mitigation measures described in the Screening Report, is not likely to cause significant adverse environmental effects.*

*The Commission decides that the public concerns do not warrant a referral to the Minister of the Environment for referral of the project to a mediator or review panel.*

*Therefore the Commission concludes that it will not refer the project to the Minister for a referral to a mediator or a review panel."*

The Commission noted that it will now proceed with consideration of the licence application under the *Nuclear Safety and Control Act* [to restart Pickering units 1 to 4] under its normal public hearing process. The reactors were placed in a guaranteed shutdown state in late 1997. A condition of the current licence requires CNSC approval to operate the rectors at power.

### Reasons for Decisions:

Subsection 20(1) of the CEAA requires that the Commission, after considering the environmental assessment Screening Report and the related comments from the public, make decisions as to:

a) whether the project is likely to cause significant adverse environmental effects taking into account implementation of appropriate mitigation measures; and;
b) whether the public concerns about the project warrant a referral of the project to a mediator or review panel under the CEAA.

The decisions of the Commission, and the reasons for those decisions, are presented below.

### 4.1 Environmental Effects of the Project

In considering the environmental effects of the project, the Commission examined the information contained in the three-volume environmental assessment Screening Report, and the information obtained during the public hearing. As elaborated further below, the Commission considers that that body of information provides the Commission with an adequate basis for making its decisions under the CEAA for this project.

The Commission examined how the project is likely to affect each of the principal components of the environment as defined in the CEAA and as addressed in the Screening Report. This includes consideration of effects on air, surface water, aquatic and terrestrial ecosystems, groundwater, human health and land resources, and changes those effects would have on socio-economic conditions.

The Commission reviewed how the various components of the environment could be adversely affected during planned normal operation of the PNGS-A, during malfunctions and accidents that may occur in relation to those operations, and from future decommissioning activities. The effects considered by the Commission are those that may be caused by radiation, and other physical and chemical agents and processes.

The Commission examined how the environment itself may impact on the project, such as from severe weather events and seismic activities. The Commission also considered how the effects of the project may combine with the effects of other projects and activities in the area to create cumulative effects on the surrounding environment and resulting changes to socio-economic conditions.

In all instances, the Commission considered how, and to what extent, the existing physical and operational characteristics of the facility, the planned improvements to the plant, and the additional specific measures identified during the environmental assessment, would mitigate the likely environmental effects of the proposed operations. The Commission also considered the adequacy of the criteria applied in evaluating the significance of the residual effects.

During the course of the public hearing, the Commission sought a deeper understanding of specific technical issues through direct discussion and questioning with hearing participants. The principal issues explored include airborne releases of tritium, tritium in groundwater, environmental monitoring of tritium, potential effects of earthquakes and component aging on plant safety, emergency response planning, sediment contamination in Lake Ontario, the adequacy of supporting data, and the assessment of effects on people's sense of personal security and community satisfaction.

With respect to releases of tritium to air and groundwater, based on data from operational experience, the Commission considers that the resulting doses to members of the public, taking into account the mitigation measures, would be well below regulatory limits and, therefore, that residual adverse environmental effects would be minor and not significant. The Commission notes that, if the project proceeds, the monitoring of tritium in air and water would form part of the environmental monitoring program.

With respect to earthquake effects, the Commission explored this issue at the public hearing with appropriate representatives of its own staff and the Geological Survey of Canada, among others. Based on the documentation presented in the Screening Report and the additional information provided during the hearing that summarized extensive recent research work and its results, the Commission considers that seismic activity is not likely to cause effects on the project that would result in significant adverse environmental effects.

The Commission also sought specific information about the general safety of the plant as a result of aging components, unresolved Generic Action Items relating to CANDU reactors, and the need for improvements in the plant systems and operations. The Commission notes that, for the purpose of this environmental assessment, the upgrades and improvements necessary for the return to service were assumed to have been completed. The Commission notes that, if the licensing process proceeds, it would need to include a mechanism to require these upgrades and improvements to be put in place; otherwise, the conclusions of the environmental assessment would not be valid for the purposes of a licensing decision.

With respect to emergency response, the Commission heard concerns about whether the current three kilometre zone set by the Province of Ontario's emergency response plan would adequately protect the public. After questioning a representative of Emergency Measures Ontario, the responsible provincial authority, the Commission is satisfied that these concerns are being addressed by the responsible provincial authority.

With respect to contamination of sediments in Lake Ontario, the Commission sought clarification of the relevance of the sampling program results presented in the Screening Report to the effects of proposed future operations on lake sediments. Despite the limitations in the sediment sampling data, the Commission concludes, from other evidence presented in the Screening Report and at the public hearing, that the effects of the project on lake sediments are not likely to be significant.

The Commission sought clarification during the hearing on the methods used to evaluate the effects on personal security and community satisfaction. The Commission did not see evidence of a trend towards widespread concern despite the increased recent publicity concerning the nuclear station. Taking this and other factors into consideration, including OPG's commitment to continued public information and consultation programs, the Commission concludes that the project is not likely to cause significant adverse effects on the community.

The Commission explored public concerns about the completeness of some of the data presented The Commission recognizes that an environmental assessment, as a planning tool, involves both information and the exercise of judgement. It is a process in which information may be sufficient although not complete, as recognized by the Federal Court[1]. In this case, for certain project- environment interactions, additional specific information of the nature typically received for the purposes of the regulatory licensing process would assist in developing a more precise prediction of the environmental effects. However, the Commission considers that the body of information available in the environmental assessment Screening Report, and as obtained through the hearing process, provides an appropriate basis for drawing conclusions with respect to the likelihood and significance of the environmental effects of the proposed project.

If the Commission approves the proposed return to service of PNGS-A, the follow-up program outlined in the Screening Report would be further detailed and integrated into the CNSC licensing and compliance process. The follow-up program is designed to evaluate the accuracy of impact predictions and determine the effectiveness of mitigation measures.

Based on consideration of above information:

**The Commission decides that the project, taking into account the mitigation measures described in the Screening Report, is not likely to cause significant adverse environmental effects.**

## 4.2 Public Concerns

The Commission also considered, under subparagraph 20(1)(c)(iii) of the CEAA whether the public concerns expressed during the environmental assessment process warranted a reference to a mediator or review panel appointed by the federal Minister of the Environment.

The other bases on which a responsible authority shall refer a project to the Minister for mediation or review panel do not apply in this case. If the Commission had concluded that it is uncertain whether the project is likely to cause significant adverse environmental effects; or if the Commission had concluded that the project is likely to cause significant adverse environmental effects that are justified in the circumstances, the Commission would have been required to refer the project to the Minister for referral to a mediator or review panel.

The Commission considers that public concerns raised during the environmental assessment, including the public hearings, do not warrant reference to the Minister for referral to a mediator or a review panel. Several reasons contribute to this conclusion, with none of the reasons being so important that it alone dominates. The reasons include the following:

i) Some of the concerns relate to matters that are outside the scope of this project-specific assessment.
ii) Some of the concerns relate to matters that can be effectively addressed in the follow up programs under the CNSC's licensing and compliance processes.
iii) Some of the concerns seemed to lack a supporting factual basis, and therefore, the Commission does not consider that a review panel would be more effective at

allaying these concerns than the Commission's hearing process.

iv) The Commission considers that a number of technical concerns were adequately addressed by the additional analyses carried out in the completion of the environmental assessment Screening Report, and in the information presented at the public hearing.

v) Some of the concerns related to technical matters on which sufficient scientific and technical material has been presented to persuade the Commission that the concerns are not well founded or would not be resolved by further review by a mediator or a panel.

The Commission considered several areas of concern expressed by the public during the course of the environmental assessment. These are found both in the summaries of information submitted at steps preceding the public hearing and at the public hearing itself. The principal concerns expressed and the Commission's views are summarized below.

A major area of public concern was that the scope of the assessment was too narrow and should have been expanded to include a consideration of the need for the project and alternatives to it, such as non-nuclear alternatives to generating electricity. The Commission does not consider that the matters of need and energy generation alternatives are appropriate for inclusion in this project-specific environmental assessment. While it is within the discretion of the Commission to consider such things as the need for the project and alternatives to the project, it is relevant to also take into account the CNSC mandate and the environmental information presented. It is possible in an environmental assessment, that severe adverse environmental consequences indicate that the proponent should consider alternatives to the project. The information before the Commission does not lead in that direction. Consideration of need for and alternatives to the project should not become an indirect means of the CNSC going into areas such as energy policy or economic regulation which are not part of its mandate[2].

In the context of this project-specific assessment, the Commission concludes that public concerns about the issues of need and alternatives to the project do not warrant a reference to a mediator or review panel.

The nuclear accident scenario that was considered in the environmental assessment was a set of accident sequences leading to severe core damage and subsequent release of radioactive material to containment, followed by controlled discharge of the containment atmosphere. Some members of the public expressed the view that the scope of the assessment should be expanded to include consideration of the effects of a nuclear accident involving severe core damage with simultaneous loss of containment. The Commission considers that such a hypothetical accident event does not have a reasonable probability of occurring and therefore is not appropriate for this environmental assessment. The CEAA does not require the Commission to consider all conceivable accident events[3]. The type of event considered was appropriate for the purposes of the environmental assessment and is consistent with the purposes and intent of the CEAA. The Commission therefore does not consider that a referral to a mediator or review panel is warranted to further examine this issue.

The Commission also heard concerns from the public about the following: general safety of the plant as a result of aging components, unresolved Generic Action Items relating to CANDU reactors, and the need for improvements in the plant systems and operations; earthquake risk; public feelings of security and satisfaction; and data gaps in the assessment. As discussed in section 3.1 above, the Commission considers that these issues were adequately addressed through the scientific and technical information submitted, the answers given to the detailed questions asked by the Commission members during the public hearing, and in the technical studies undertaken as part of the assessment. The Commission therefore does not consider that a referral to a mediator or review panel is warranted to further examine these issues.

The public also expressed concern over OPG's public consultation programs undertaken as part of this environmental assessment and in the composition and conduct of OPG's Community Advisory Council. During the environmental assessment process, as directed by CNSC staff, OPG employed a variety of public consultation tools and methods, including newsletters, notification letters, stakeholder briefings/interviews, open houses, mail-back postcards, committee meetings, workshops, mall displays, community centre/library displays and the Internet. The Commission recognizes the importance of sustained, effective and meaningful public consultation between major facility operators and the public and also OPG's commitment to continue to improve its public involvement program. CNSC will continue to follow-up with OPG on this issue as part of the CNSC licensing and compliance process. The Commission notes that this is an issue that can be addressed without the need for referral to a mediator or review panel.

Some members of the public expressed the view that a review panel would be more independent and objective than the Commission. Members of the Commission are appointed by the Governor in Council and constitute an independent regulatory body. All members are fully independent and serve on a fixed-term basis. They are therefore as free from bias as potential members of a review panel would be. The Commission rejects any suggestion of a lack of impartiality.

Based on consideration of the above:

The Commission decides that public concerns do not warrant a referral to the Minister of the Environment for referral of the project to a mediator or review panel.

1 Alberta Wilderness Association v.Express Pipelines Ltd.(1996),137 D.L.R. (4th) 177 (F.C.A.)

2 Sharp v. Canada [1999] 4 F.C. 363 (C.A.)

3 Inverhuron & District Ratepayer's Association v. Canada (2000), 34 C.E.L.R. (N.S.) 1(F.C.T.D.)

# GENERAL news

## CNSC approves environmental review of PICKERING A

The Canadian Nuclear Safety Commission has accepted the conclusions of the environmental screening report on the return to service of the Pickering A Nuclear Generating Station owned by Ontario Power Generation.

The CNSC concluded that the return of the four nuclear reactors at Pickering A to service producing electricity would not have significant adverse environmental effects, and that the degree of public concern expressed regarding the proposal to restart the four reactors was not sufficient to warrant deferring the matter to the federal Minister of the Environment for a public panel review.

Ontario Power Generation is now free to undertake the necessary repairs and upgrading of systems to be done before applying to the CNSC for permission to restart the reactors.

*(See the full text of the CNSC's "Reasons for Decisions" elsewhere in this issue.)*

## New president at AECL.

In early February, 2001, Ralph Goodale, Minister of Natural Resources Canada, announced the appointment of **Mr. Robert G. Van Adel** as President and Chief Executive Officer of Atomic Energy of Canada Limited (AECL) for a five-year period, effective February 5, 2001. Mr. Van Adel replaces Mr. R. Allen Kilpatrick, who became President in 1998.

"Mr. Van Adel brings a wealth of experience to this important corporation, which plays a critical role in the Canadian energy industry," said Minister Goodale. "He has a good track record of achieving results through effective operations, teamwork and motivation of people."

Most recently Mr. Van Adel was President of AMEC AGRA Engineering Inc., a group of international companies specializing in engineering and construction services.

He began his career at the Anti-Inflation Board and moved to the Export Development Corporation in 1976, where he held increasingly responsible positions primarily in export financing. He was Executive Vice President of Financial Services when he left the public service in 1994 for a senior executive position with the AGRA group of companies, which merged with AMEC in April 2000.

Mr. Van Adel has served on a number of boards, most recently the Transportation Association of Canada, the Canadian Council for Public-Private Partnerships and Canatom NPM Inc. He received his Bachelor of Commerce and his Master of Arts in Public Administration from Carleton University.

In his parting remarks Allen Kilpatrick said, "I leave in no doubt that nuclear power has a bright future even though we are likely to go through a period of some years before we see a resurgence f new plants."

## U of T SLOWPOKE dismantled

On February 8, 2001, the University of Toronto applied for (and subsequently received) a licence from the Canadian Nuclear Safety Commission to abandon its SLOWPOKE 2 reactor.

The work of dismantling the reactor took place over the fall of 2000 by a team headed by Dr. James Smith of the university with the firm Merlin-Simex, which is headed by Jack Richman, a former president of the Canadian Nuclear Association, doing most of the work.

The U of T SLOWPOKE 2 was the second such reactor at the university. The first SLOWPOKE reactor outside of Atomic energy of Canada Limited (SLOWPOKE 1) was installed in 1971. It was replaced with an upgraded model in 1976.

The SLOWPOKE design is a small, inherently safe, reactor intended primarily for activation analysis. It is a light water moderated pool design using a very small core of highly enriched uranium, with a maximum power of 20 kW(th).

Some parts, including the beryllium reflector plates, irradiation tubes, irradiation controller and sample receiver were shipped to the University of West Indies in Jamaica which has a SLOWPOKE 2 reactor.

The only significant incident in the dismantling occurred when it was discovered that the beryllium reflectors presented a higher radiation field than anticipated. Additional led shielding was brought in and the parts subsequently safely packed. Local 1998 of the United Steel Workers of

America, representing many of the staff at the university, intervened in the CNSC hearing to express concern bout the handling of that unanticipated situation but acknowledged that no one was over exposed.

## Indian reactors ride through earthquake

The Nuclear Power Corporation of India (NPCIL) reported that the two-unit Kakrapar nuclear power plant in the Surat district of Gujurat continued to operate safely and normally following the devastating earthquake which struck the region on January 26, 2001, . The Kakrapar plants are 250 MWe units using a CANDU design based on the Douglas Point plant built on the current Bruce site in the 1960s. Like all other Indian reactors, the Kakrapar plant is designed to withstand high-intensity earthquakes. Other nuclear power reactors sited further away from the earthquake's epicentre were also reported to be unaffected and continued to operate safely.

## Romania reportedly to complete Cernavoda

According to the Uranium Institute the new Romanian government is to invite tenders to complete three more nuclear reactors at its Cernavoda nuclear power plant. Work on Cernavoda-2 was suspended due to lack of funds but the government hopes to have the reactor operational by 2004. The CANDU 6 Cernavoda-1 unit provides about 10 per cent of the country's electricity needs.

## Bruce Power applies for licences

Bruce Power Inc. has applied to the Canadian Nuclear Safety Commission for licences to operate Bruce A and Bruce B nuclear generating stations. The first day of the Commission's two-day hearing process was held February 8, 2001. Representing Bruce Power were: Robin Jeffrey, CEO of Bruce Power, Duncan Hawthorne, chief engineer, and Robert Nixon, currently with Ontario Power Generation but soon to be appointed executive vice-president production at Bruce Power.

The CNSC staff noted that this application presents a unique situation, with a new company applying to operate existing power reactors as distinct from the past with established organizations applying for new plants. Under the Nuclear Safety and Control Act licences may not be transferred.

Bruce Power plans to retain, to a large extent, the existing OPG organization, staff, programs, policies and procedures. Most of the existing staff at the Bruce site will be transferred to Bruce Power along with some specialized support staff currently in OPG's centralized support services.

Bruce Power Inc. is the general partner of Bruce Power Limited Partnership. The other partners are British Energy (79.8)%), Cameco Corporation (15%), Power Workers' Union (4%) and the Society of energy Processionals (1.2%).

As a private company whose only income will be from the sale of electricity generated by the plants CNSC staff asked for, and obtained, financial guarantees that Bruce Power could maintain the plants in a safe shutdown state if necessary.

CNSC staff reported that they concluded Bruce Power is qualified to operate Bruce B and maintain Bruce A in its current de-fueled shutdown state and recommended issuance of operating licences to Bruce Power for the Bruce A and B stations.

The second day of the hearing is scheduled for April 19, 2001.

## Application for MAPLE Operating Licence

Atomic Energy of Canada Limited has formally applied to the Canadian Nuclear Safety Commission for Operating Licences for the two MAPLE reactors constructed at the Chalk River Laboratories. The first day of hearing, under the CNSC's two hearing day policy, is March 8, 2001 with the second day scheduled for May 29, 2001.

The two MAPLE reactors are small (10 MWth) reactors devoted to the production of radioisotopes. They are small pool type reactors with low-enriched uranium fuel. (See CNS bulletin, Vol. 17, No. 4, Autumn 1996 for a generic description.) AECL has built and will operate the reactors under an agreement with MDS Nordion. A construction licence was issued by the Atomic Energy Control Board in December 1997 and the original schedule called for MAPLE 1 to be in production by May 2000 and MAPLE 2 by December 2000.

A number of problems arose during commissioning, including malfunctions of the control absorber rod and shut-off rods. The CNSC and AECL have both conducted reviews of these mishaps with the report from the CNSC staff "Incident Inspection Team" to be presented to the Commission at its meeting of March 8, following the hearing scheduled for the same day. CNSC staff have recommended a condition to be included in the licence that the shut-off problem be resolved to CNSC staff satisfaction prior to start up.

# In memoriam

***Ed. Note:*** *For the following remembrance we are indebted to John Foster, a former president of Atomic Energy of Canada Limited. As in his note on Harold Wilson (CNS Bulletin, Vol 20, No. 4) John provides further insight into the early years of the Canadian nuclear power program.*

## WILLIE WILSON

### First Engineering Manager in what has become AECL CANDU

On December 1, 2000, Ivan Laverne (Willie) Wilson died at his home in Barrie, Ontario. He was in his 84th year.

Willie Wilson was born in Hamilton, near his home in Dundas, Ontario, on May 20, 1917. He entered the University of Toronto in 1934 and graduated in 1939 with an MA in Mathematics and Physics. During World WAR II he was one of a select group of Canadians chosen to work with the British in the development of the gas turbine at Powerjets.

Following the war he went to the Chalk River Nuclear Laboratory, where he was one of that brilliant staff working in the Reactor Physics Division, under George C. Laurence.. It was here that he began to rub shoulders with the Nuclear Power Group.{1} In 1957 he was one of the Chalk River team chosen to review the work of Canadian General Electric in converting NPD from a pressure vessel to a pressure tube design.

At the end of 1957, Atomic Energy of Canada Limited (which had been formed in 1952) had decided to proceed to the second step in the development of the Canadian power reactor. NPD, the 20 MWe prototype was the first step. The second step was to be a unit of commercial size, 200 MWe. AECL would perform the design itself.

To this end it would establish a new division, NPPD – Nuclear Power Plant Division, on Ontario Hydro property in Toronto. Harold Smith, of Ontario Hydro and head of the Nuclear Power Group would be Division Director *pro tem.* Harold Smith would take Mel Berry, whom he had taken to Chalk River four years before, back to Toronto as Manager of Development. B.P.Scull was chosen as Manager of Administration, and Willie Wilson as Manager of Design. I was subsequently enlisted as Deputy Director of the Division. He would effectively be the Director, since, at this same juncture, Ontario Hydro was appointing Harold Assistant General Manager, Engineering, Construction and System Planning for the Commission. He would have little time to devote to NPPD. The new Division would be staffed initially with 15 Ontario Hydro engineers and a similar number of engineers and scientists from AECL. The Division occupied its quarters in Toronto in February 1958.

The original intention was to perform two years' studies, but orders came in early 1959 to proceed with what would become the Douglas Point project.

### Douglas Point

Douglas Point was the basically same as NPD in that it would use a natural uranium fuelled, heavy water moderated and cooled, pressure tube reactor. In addition the Douglas Point design adopted four features from NPD, two that dated back to NPD 1, two from NPD.

The first pair were the fuel cross-section – 19 round rods with .05 in. spacing in a 3.25 in. bore tube – and the choice of carbon steel for the Primary Heat Transfer System piping. The second pair were the length of the fuel bundle - 19.5 in. – and the sealing disc invented by W.H.Bowes for the channel closure.

In all other respects Douglas Point was different in detail from NPD, due largely to the great disparity in power, although there were many other departures for other reasons.

One of the first departures, and one in which Willie Wilson was instrumental, was the choice of thin-walled welded zircaloy tubing, which had recently become available, for calandria tubes. Not only did zircaloy provide a much more robust tube than the aluminum used in the research and NPD reactors, it made it possible to use stainless steel in place of aluminum for the reactor vessel.

Two other early departures were Willie's decision that the fuel machine should handle a pair of fuel bundles at a time, and his insistence that, during fuelling operations, the fuel string be under control of both machines at all times.

Pairs of fuel bundles were still short enough sections of fuel for efficient use of the fuel. Handling the bundles in pairs meant each chamber in the fuelling machine magazine would carry two bundles in tandem. This made it possible to design a fuelling machine head with a reasonable diameter.

NPD took advantage of the coolant flow in the channel to hold the fuel string together, by designing the fuelling machines to fuel against the flow. With the fuel string under control of the rams at both ends, the Douglas Point machines were designed to fuel with the flow. The merit of this became apparent 30 years later when analyses of Large Loss of Coolant Accidents in Ontario Hydro reactors led to significantly downrating reactors that were fuelled against the flow.

Willie Wilson's main role during the design of the plant was in establishing and insisting upon high standards in the quality of the work. There could be no easy reliance on suppliers' or other data. They must be verified and shown to have a valid basis before they were used. Similarly extreme care must be taken in ensuring the applicability of codes formulae.

A particular example of this was the veracity of statements in the Douglas Point Safety Report. Willie Wilson wrote parts of this himself, and assiduously reviewed all the report through its many revisions.

1 The Nuclear Power Group was a set of nine engineers from Canadian industry sent to Chalk River at the beginning of 1954 to explore, with AECL staff, the feasibility of developing the heavy water reactor for power production.

## After Douglas Point

By 1966, when the engineering and construction of Douglas Point were coming to an end, NPPD, or Power Projects as it was then styled, was already engaged in the engineering of the RAPP reactors for India and the Pickering reactors for Ontario Hydro. New leaders had been developed to lead these projects.

About the same time Power Projects was moving out of its old Ontario Hydro premises into its new quarters at Sheridan Park. Part of these was the Sheridan Park Engineering Laboratory (SPEL). Mel Berry, Manager of Development, retired soon after because of his physical condition.

This gave me the opportunity to put Willie Wilson in charge of SPEL. .This provided experienced professional leadership for the Laboratory, and provided an opportunity for Willie to indulge his interest in automation.

## Willie Wilson's Contribution to the CANDU line of reactors and to AECL CANDU.

A new organization setting out on a ground-breaking engineering enterprise has three main tasks, each as important as the others:

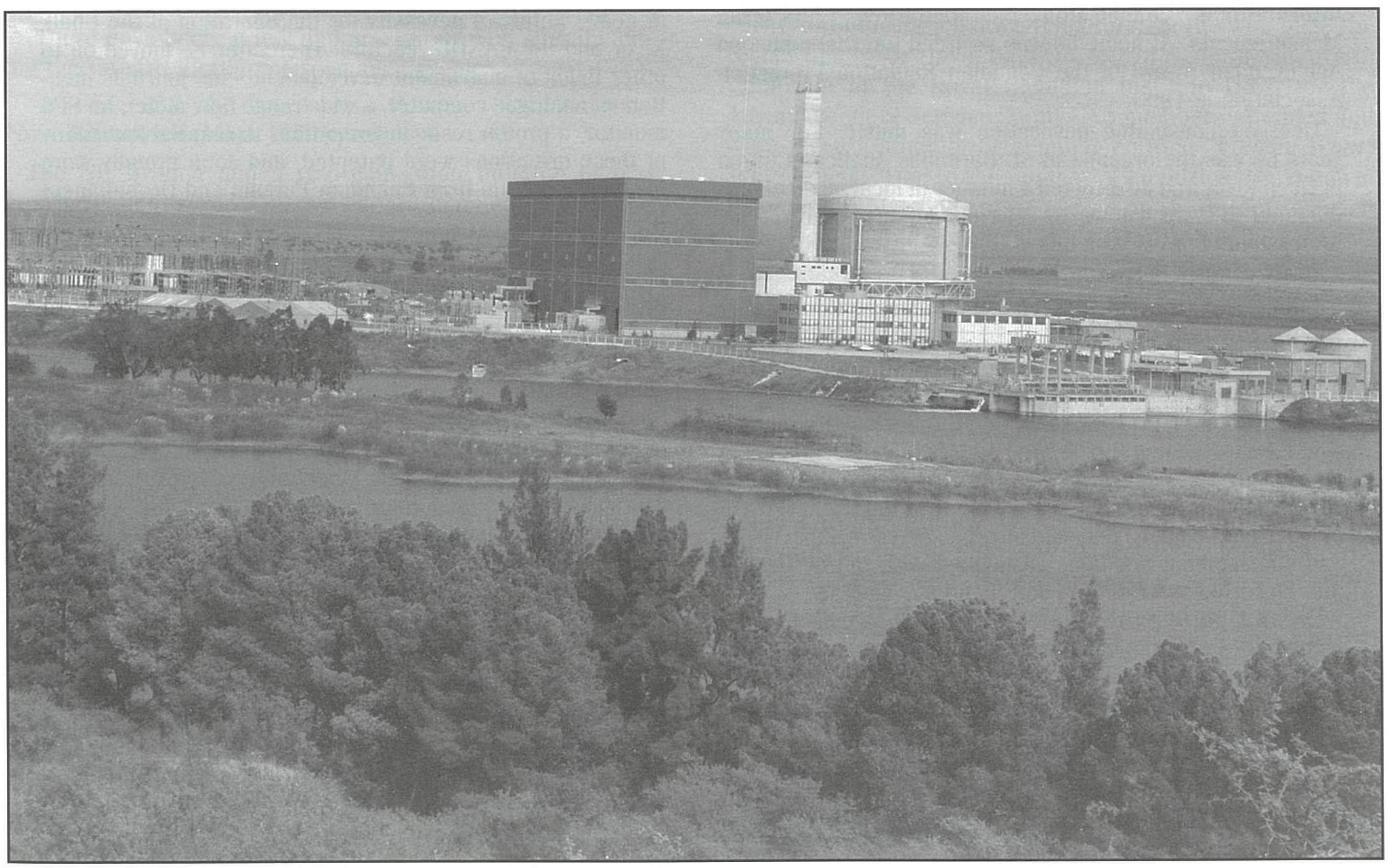
1. Creation of the organization itself
2. Creation of a new design *in toto,* and
3. Conduct of all functions associated with execution of a project

Willie's main role, of course was on the second task – production of an original design. Nevertheless, he made a major contribution to the first – creation of the organization itself.

At our weekly staffing sessions, the managers entered into the deliberations on all candidates, not just those for their own departments, to ensure a compatible organization. Willie's broad knowledge of the skills required and the merits of various qualifications, and his good judgment of personal attributes played a major part in forging the character of the new organization that would ultimately grow into AECL CANDU.

As the first Manager of Engineering of what became AECL CANDU, Willie Wilson led the creation of the basic CANDU design, and the creation and training of the team that would go on to design later versions, and established many of the principles and working habits that would guide them.

Willie Wilson was the soul of integrity. His insistence on veracity characterized everything he did. He was a thoroughly good person who was warmly liked by all who knew him.



*A view of the Embalse (CANDU 6) plant in Argentina.*

# OBITUARIES

**George Cowper**

George Cowper died December 16, 2000, in Deep River, Ontario, where he had lived for more than 50 years.

George was born in the United Kingdom in 1921. After graduating from Durham University in 1943 he worked on radar at the telecommunications Research Establishment. He came to the Chalk River Project in 1948.In 1958 he was appointed head of radiation dosimetry and health physics it what had become the Chalk River Nuclear Laboratories of Atomic Energy of Canada Limited.

Through the next two and half decades George guided the application of new technology to the problems of measuring radiation and radionuclides. His group produced several generations of portal monitors, tritium and iodine monitors, criticality monitors and film and thermoluminescent dosimeters.

He served on a number of committees in Canada and abroad. For several years he was on AECL's Nuclear Safety Advisory Committee and was on committees of the Defence Research Board, the National Research Council, and the Canadian Advisory Committee for the International Standards Organization. Outside Canada he served on an advisory committee for the Oak Ridge National Laboratory in the USA and was a visiting professor at the Bhabba Research Centre in India. Internationally he was on several task groups for the International Atomic Energy Agency, the International Commission of Radiological Protection and the International Commission on Radiation Units and Measurements. At home he was awarded the Distinguished Achievement Award of the Canadian Radiation Protection Association in 1993.

George's consuming advocation was music. For many years he was the organist at St. Barnabas Anglican Church in Deep River and he directed a number of local musical productions. He was known to seek out organs wherever his professional travels took him.

**John (Jack) Edmund SMITH,** one of the early members of what is now AECL CANDU, died February 26, 2001 at the age of 68.

Jack joined the Power Projects part of Atomic Energy of Canada Limited in 1960 after a stint with Avro Aircraft where he worked on the ill-fated Avro Arrow. Specializing in instrument and control he was involved in the design and commissioning of Douglas Point, the first full scale CANDU nuclear power plant. Subsequently he served in supervisory and management positions associated with the designs of the Pickering A station, Point Lepreau, Gentilly -2, and Wolsong 1. After retiring in the early 1990 he consulted on a number of projects including assisting Point Lepreau with its Y2K program.

Former associates remember him as a brilliant engineer who was easy to work with and for. Jad Popovic comments that he hired her at a time when few women engineers were being hired. He was, she said "technically very competent and an inspiring engineer". He is survived by his wife, three daughters and four grandchildren.

**John G. Bayly - 1918-2001**

John Bayly, a member of the small team of the Montreal Laboratories in the 1940's, died in Deep River, Ontario on January 10, 2001, in his 84th year.

John was born in Comox, B.C. in August 1918 as WWI was winding down. His father was a surveyor for the federal government, and since his work was mostly in northern Canada, he usually located his family somewhere south of his work area. The family's next move was to Saskatchewan, and finally to the Lindenlea district of Ottawa. Here John received his schooling, graduating from Lisgar Collegiate in 1938 with a 4-year scholarship to Queen's.

During the war, physics research at Queen's was oriented towards radar, and John, worked in this field while obtaining a Master's degree. He was invited to join the top secret Atomic Energy Project - first at the Montreal Laboratories, and later at the mysterious "Chalk River Project".

John described himself as a physicist, which he was, not in the esoteric fields of mesons, and quarks and gluons, but in a solid understanding of classical physics. This he combined with a fertile imagination and broad mechanical, electrical, and electronic skills. He was, in fact, a real inventor, with the ability and drive to bring his concepts to fruition.

At Chalk River, John joined the Nuclear Physics Branch and was in charge of some of the early experiments in ZEEP - the first reactor to be built outside the US. Next he developed a variety of instruments for the detection and analysis of heavy water - a necessity for the operation of the Chalk River and the CANDU reactors. Thereafter he moved on to other fields of instrument development - his journals mention an analogue computer, a wide range flow meter, an SF6 monitor, a proton resonance monitor, to name a few. Many of these inventions were patented, and John proudly wore his "Inventor" pin from Canadian Patents and Development Ltd.

In retirement he escaped the cold of Canada's winters, which he strongly disliked, travelling to havens of the southern US, Mexico, Belize, Costa Rica, and, on one occasion, in the south of Spain. But then he and his wife Rosalind discovered Australasia where real summer prevails during our winter months. From then on they were regulars in Australia, New Zealand, Fiji, Raratonga, and Hawaii, until health problems put an end to such distant excursions.

John's gentle manner, his kindly nature, his dry wit, his wise advice, his generous assistance, and his genuine friendship have impinged on many people in many ways - but most certainly all for the better. His parents Christened him "John Goodenough Bayly" - but surely that is an understatement. To his family and friends he was not just "good enough", he was "tops" ! He will be greatly missed.

*Ed. Note: Our thanks to Chas. Millar who presided at the memorial service for John Bayly and whose words served as the source of the above note.*

# BRANCH ACTIVITIES

At the time of publication only a few Branches had submitted reports on their activities, as follows:

### Chalk River (Michael Stephens)

The Chalk river Branch held an open seminar on January 25 with guest speaker Alistair Miller, Manager, Heavy Water Technology, AECL. He titled his presentation "Heavy Water: Manufacturers' Guide for the Hydrogen Century".

As part of its education program the Branch will be purchasing the book, *"Heavy Water and the Wartime Race for Nuclear Energy"*, by Per F. Dahl (1999), for the W.B. Lewis Public Library in Deep River.

The next Branch seminar is scheduled for March 29, with the topic to be announced later.

### Manitoba (Morgan Brown)

Unfortunately the seminar planned for Feb 19 fell through when the speaker (Ingo Beckmerhagen of Germany) was not given permission to visit by his workplace (he was en route to a conference).

Bob van Adel, the new president of AECL, declined an invitation to speak to the CNS Branch since he plans to visit all the AECL sites to speak to all staff .

There have been a few updates to our web site, including the CANDU lifetime performance graph.

### New Brunswick (Mark McIntyre):

The NB Branch had a re-organization meeting in mid February and several activities all planned during the month of March. On March 16 Graham MacDonald from Siemens-Framatome will to talk about the recent merger of those two companies. On March 31 Rod White, VP Nuclear of NB Power, will be the guest speaker at our Branch dinner.

### Ottawa

An interesting, extensively illustrated, talk was given by Dr. Bob Truong of the CNSC, February 22, on *"Potential Applications of Remote Sensing in International Safeguards"*. Bob reviewed the role of the Commission in carrying out Canada's obligations under the international safeguards regime and then presented numerous illustrations to show how remote sensing from satellites can be used to ensure that there is no clandestine activity.

The next meeting will take place March 12 with Paul Turinsky of North Carolina State University speaking on *"Nuclear Power South of the Border"*.

Again this year the Branch is offering a prize at the local Ottawa Regional Science Fair which takes place April 7.

### Quebec (Guy Marleau):

The main activity of the branch was to participate, via the Institut de génie nucléaire, in the open house held at École Polytechnique de Montréal on January 28 2001. The Institut de génie nucléaire had a small booth where we presented our activities in nuclear engineering. This exposition attracted a large number of engineering students as well as the attention of the general public that visited École Polytechnique.

### Toronto (Adam McLean)

The Toronto Branch has had another very active and noteworthy month of activity.

Dr. Jerry Cuttler delivered his intriguing talk entitled *"Curing Cancer with Low Doses of Ionizing Radiation"* on February 8th in the OPG Main Auditorium. Those that attended showed both keen interest and desire for more information on the topic, something that Jerry is always willing and able to provide. Following this presentation Jerry has been invited to give the talk at the Radiation Safety Institute of Canada for researchers at the RSI, local members of the Canadian Radiation Protection Association (CRPA) and interested members of the public at 3:00 PM on Thursday March 22, 2001.

The Toronto Branch advertised through the web page the recent talk by Dr David Baldwin, V.P. of General Atomics in California to the Royal Canadian Institute (RCI) for the Advancement of Science Many CNS members attended and were given a stimulating seminar entitled *"Fusion: What? Why? When?'* Due to the number of enquiries, Dr. Baldwin has allowed his slides to be posted on the Toronto Branch web page for free download.

In support of Engineering Week, the Toronto Branch is advertising a talk by Mr A.K. Stuart, Chairman of Stuart Energy Systems entitled *'Towards a Hydrogen Economy'* taking place Tuesday March 6th, in the Medical Science building at U of T.

Volunteers are sought to help out with judging for the Toronto Science & Technology Fair! Visit < www.scitechfairs.toronto.on.ca >. The times and venues area: Saturday, March 24, at Centennial College (Toronto East); Saturday, March 31, location TBA (Toronto West), and, Saturday April 7 at the University of Toronto for the final Toronto regional fair.

Finally, behind the scenes, much additional work has been done on the Toronto Branch web page:

Some examples are:

- a colourful layout on a dark background making use of the new 3D logo
- a new up-to-the-minute scrolling 'billboard' presents the latest news and 'Branch Information'

*continued on page 41*

# CNS news

## CNS plans active year

The Canadian Nuclear Society has plans for an active year 2001.

Coming up shortly is the ***Reactor Safety Course*** which will be held at the Sheridan Park Centre on April 25 to 27. This course which has been offered for several years and is being constantly updated has been one of the most popular offerings of the Society with the last several courses being over subscribed. It is intended to give an introduction to the concept, principles and analysis of the safety of CANDU reactors. Information has been mailed to all members and there is a notice in this issue of the *CNS Bulletin.*

The large event of the year is the ***CNS Annual Conference*** which will be held again at the Delta Chelsea Hotel in downtown Toronto, June 10 to 13. Last year's conference, the first such national event sponsored solely by the CNS, was a great success. (The previous national conferences had been joint ones between the CNS and the Canadian Nuclear Association).The organizers of this year's event are building on that and, with the participation of organizations associated with the Canadian nuclear program, hope to present an even better show than last year. A large number of technical papers have been submitted and are being reviewed. Invitations have gone out to special speakers for the plenary sessions and many have already accepted. Look for the registration form printed in this issue of the *CNS Bulletin.*

In the fall the ***7th International on CANDU Fuel Conference*** will be held in Kingston, Ontario, from September 24 to 27. The last fuel conference held in Niagara Falls in September 1999, drew over 120 specialists from around the world. This year's organizers boast that they will offer an even better conference and associated social activities than the very successful one two years go.

Also in the fall the CNS is serving as the prime sponsor for the ***2nd Climate Change Symposium.*** The first such meeting brought together, for the first time, representatives of the many different energy technologies to discuss the potential contribution of each in the fight against global warming. This symposium will be held in Toronto. Preliminary notices have been sent out. For information now contact Duane Pendergast, e-mail: duane.pendergast@computare.org.

There is always need for additional members for the organizing committees of these many CNS events. This can be a challenging and interesting activity where you can combine your technical knowledge of the particular subject with your ability to organize and interact with others. Contact any of the CNS executive for further information.

And, a reminder of the ***Nuclear Industry Winter Seminar,*** organized by the Canadian Nuclear Association with the cooperation of the Canadian Nuclear Society, which will be held in Ottawa, March 26 and 27. This is the annual concise overview of the Canadian nuclear industry, with presentations by many of the leaders of the industry. See the advertisement elsewhere in this issue of the *CNS Bulletin.*

### Renewal Reminder

Dear CNS member:

Membership renewal letters for 2001 were mailed out in October. If you have already renewed, thank you. If you have not yet, please take a minute right now to do so – it is already almost the end of February as I write this. If you have not received your renewal letter, or are not sure where it is, don't worry, just contact the CNS office at: tel. 416-977-7620, fax 416-977-8131, or e-mail < cns-snc@on.aibn.com >. Thank you for your continued interest in the CNS.

### Rappel au renouvellement des adhésions

Cher/chère membre de la SNC:

Les lettres de renouvellement des adhésions pour 2001 ont été empostées en octobre. Si vous avez déjà renouvelé, nous vous en remercions. Sinon, je vous prie de prendre une toute petite minute pour le faire tout de suite – c'est déjà presque la fin février au moment où j'écris ces lignes. Si vous n'avez pas reçu votre lettre de renouvellement, ou si vous l'avez égarée, ne vous en faites pas, vous n'avez qu'à contacter le bureau de la SNC par téléphone au 416-977-7620, télécopieur au 416-977-8131, ou courrier électronique au < cns-snc@on.aibn.com >. Je vous remercie de l'intérêt que vous continuez à porter à la SNC.

Ben Rouben
Chairman, Membership Committee
Président du comité des adhésions

*continued from page 39*

- past events are organized in reverse-chronological order back to 1999 (new this year - pictures!)
- 'Links to the Toronto Community' presents links for EVERY company/school/institution represented by Toronto Branch members with a short description of each service
- a 'Low Dose Radiation' page has been set up to provide links and published scientific papers on the topic to date.
- a short *'Canadian CANDU: Why you should be Proud'* page has been started based around a presentation given by A. McLean for all term coop students at OPG to encourage them to get interested in and excited about nuclear science and engineering.

We encourage EVERYONE to take a look and send us their comments and impressions of the site. Please let us know what you think. < www.cns-snc.ca - branches - Toronto.

## *CANDU Reactor Safety Course*

### *April 25 - 27, 2001*

### *Sheridan Park Conference Centre*

***Outline***

This course will provide an overview of the safety aspects of CANDU design and licensing philosophy. Topics will include overviews of: design and licensing fundamentals, safety-related systems, environmental issues, deterministic and probabilistic safety analyses, core physics safety analysis, severe core damage assessment, and safety R&D.

There will also be a tour of AECL's Commercial Products and Field Services (CPFS) facility.

To register or for information contact:
Denise Rouben, CNS office, 416-977-7620,
e-mail: cns-snc@on.aibn.com

# New members

We would like to welcome the following new members, who have joined the CNS since the previous Bulletin issue.

Nous aimerions accueillir chaudement les nouveaux membres suivants, qui ont fait adhésion à la SNC après la parution du Bulletin précédent.

| | |
|---|---|
| Emil Robert Bros | Ontario Power Generation TSSD |
| Peter J. Schurmann | Siemens Canada Limited |
| Mike Richard Barnwell | Barnwell Consulting Inc. |
| Ray Silver | Journalist |
| Ana Stefania Soare | Atomic Energy of Canada Limited |
| Gina-Mihaela Toma | CNE-PROD Cernavoda |
| Alan Stuart Gray | Atomic Energy of Canada Limited |
| Sarah Hodgson | Candesco Research Corp. |
| Linda C.F. Wrigley | |
| Pascal Olivier Hernu | Atomic Energy of Canada Limited |
| Marc Langan | Candesco Research Corp. |
| Valerie F Vance | AECL |
| Nagaraja Rao | AECL |
| Hormoz Azizian | IR Technologies Inc. |
| Nigel Reynolds | AECL |
| Rama Subramanian | AECL |
| Anne M. Williams | AECL |
| Christopher Riehl | Ontario Power Generation |
| Christina Van Drunen | AECL |
| Larry Nichol | Ontario Power Generation |
| Don McGregor | GasTOPS Ltd. |
| Mary Isabel Moore | Retired |
| Claire Flood | New Brunswick Power |
| Charlie Hickman | New Brunswick Power |
| Marc Aubray | Hydro-Québec |
| Ebru Nihan Önder | École Polytechnique de Montréal |
| Mihaela F. Ion | Canadian Nuclear Utility Services |
| Jinchao Mao | AECL |
| Alina Nainer | AECL |
| Tony Edward Harras | |
| Doug John Bieman | Ontario Power Generation |
| Michael La Fontaine | Imaging & Sensing Technology |
| David Fenton Brophy | Nuclear & Fossil Power Services |
| Penny D. Neal | AECL |
| Ian Grant | Canadian Nuclear Safety Commission |
| Adrian Popescu | Ontario Power Generation Inc. |
| Wagih Wassef Ghobriel | University of Toronto at Mississauga |
| Robert L. Hemmings | Canatom NPM Inc. |
| Hymie Sol Shapiro | ECL |
| Christopher M. Bailey | Cantech Associates |

# CNS CANDU Chemistry Course:

## - A Formula For Success

*by Bill Schneider*

The Canadian Nuclear Society **CANDU Chemistry Course 2001** was a success - it was fully registered, the course content addressed a range of perspectives and the presenters expertly assembled and presented a large amount of exciting material.

Held February 19 and 20, 2001 at the Babcock & Wilcox Canada facility in Cambridge, Ontario, the event was sponsored by the CNS Design and Materials Division.

The 47 registrants represented a range of CANDU organizations including: CNSC, NIAC, Siemans, BWC, DMI, NB Power, OPG (all sites) and AECL. In addition, Ms Luminita Mocodean of CNE. PROD. CERNAVODA made a special trip from Romania for the course. She said, "I'm a process engineer so I was impressed with the fact the course provided some unique learning opportunities that I haven't seen in courses in Europe. It's very practical content and that's what I need."

The course was organized as an introduction to the subject for people involved with design, materials, construction, operation and maintenance of plant systems and was therefore not targeted to established chemistry specialists. From that perspective the registrants came to the course with a range of systems and equipment experience as well as a fair degree of enthusiasm for the material.

The stars of the course were the presenters *(see photo):* Dr. John Elliot, Dr. Carl Turner, Dr. Peter Angell (all AECL-CRL), Dr. Victor Murphy (AECL-SP) and John Jevec (B&W McDermott Technologies Inc of Alliance, OH). All of the presenters are expert and active in their field and each assembled substantial materials for their presentation. The information was supported with real data from actual operation - made available through the support of the CANDU Owners Group (COG) and its member utilities.

The course was organized by Bill Schneider, Manager, Nuclear Technology & Engineering Service, Babcock & Wilcox Canada, with the assistance of Ed Price who has, over the years, initiated many CNS Conferences, workshops and courses.

The course addressed reactor and primary heat transport systems, secondary heat transport systems and cooling service water systems. As a starting jolt, the registrants were served a "primer" on both primary side and secondary side chemistries. Many of the attendees closed the book on chemistry when they left school - undoubtedly with a big sigh of relief. The primers were therefore a vital starting point for the course.

After the primers, the course went on to identifying the numerous systems in a typical plant, the equipment configurations involved, the materials of construction and also normal and off-normal chemistry, materials degradation and plant emissions considerations. Informal interaction among participants is an important part of such events. Coffee breaks, the lunches and a reception and dinner at the Riverbank Steakhouse (one of the many fine stone buildings in Cambridge's historical Old Galt district) gave the group time to network and build relationships.

The course included a B&W facilities tour which was well received by those who don't usually deal directly with hardware, especially by people who work with equipment in operation but normally only get to look at the equipment's insulation. A review of activity at BWC since the '50s including the design, engineering, construction and servicing of 223 CANDU steam generators and 40 PWR replacement SGs was presented prior to the tour by Michael Lees, G.M. BWC Nuclear Steam Generators & Components Program. The tour afforded a view at various stages of construction of four replacement steam generators for the Calvert Cliffs plant at Baltimore (CE Type) and six steam generators for the Duke Power Oconee plant (B&W OTSG type). These plants are respectively the first and second to have applied for and received 20 year license extensions from the USNRC - a good sign for long term optimism in the nuclear industry; and also an indication that the kind of training provided at this course will be needed for some time to come.

Canadian Nuclear Society
22nd Annual Conference
Delta Chelsea Inn, Toronto, Ontario
2001 June 10-13

## REGISTRATION FORM

(Please type or write in block letters)

Name: ______________________________
(Dr./Mr./Ms.) First Last

Title: ______________________________

Organization: ______________________________

Business Address: ______________________________
Street # Street Name

______________________________
City Province/State

______________________________
Postal Code Country

Business Telephone: ______________________________

Fax: ______________________________

E-mail: ______________________________

Are you a Speaker? ❑ Yes ❑ No

Would you like vegetarian meals? ❑ Yes ❑ No

This registration form is also available on the CNS web site, at www.cns-snc.ca.

For further information regarding the Conference, please contact Denise Rouben, CNS Office Manager, at:
Tel: 416-977-7620
Fax: 416-977-8131
E-mail: cns-snc@on.aibn.com.

Hotel booking must be made directly with the Delta Chelsea, at 416-243-5732 or 1-800-243-5732. When calling the Chelsea, you must indicate that the reservation is for the CNS Annual Conference (Code Name is GCMCNS). A block of rooms is held for the Conference until 2001 May 11. The price of rooms is $189 per night + tax, single or double. Smoking or non-smoking rooms are available upon request.

*For Office Use:*

CNS Member?
ID #:
Entered:
Processed:
Receipt sent:

## REGISTRATION OPTIONS

| Registering: | By May 11 | After May 11 |
|---|---|---|
| CNS Member | $530.00 ❑ | $600.00 ❑ |
| Non-CNS Member | $595.00 ❑ | $665.00 ❑ |

(Includes all CNS Sessions, one copy of Proceedings, Reception, Conference meals including Banquet)

| | | |
|---|---|---|
| CNS Retiree Member | $160.00 ❑ | $200.00 ❑ |
| Full-Time Student | $160.00 ❑ | $200.00 ❑ |

(Includes all CNS Sessions, one copy of Proceedings, Reception, Conference meals including Banquet)

One-Day Registration (Includes sessions and Conference meals for day – Luncheon on Mon. or Wed., Banquet on Tues.) Does not include CD-ROM Proceedings.

| | | |
|---|---|---|
| CNS Member | $280.00 ❑ | $310.00 ❑ |
| Non-CNS Member | $310.00 ❑ | $340.00 ❑ |

Guest accompanying registrant – Free ❑
(Includes Reception only)
Guest's Name: ______________________________

Extra Luncheon Tickets: ....@ $35 = ---------
For which day? ❑ Mon ❑ Wed

Extra Banquet Tickets (Tues): ...@ $65 = --------

Extra CD-ROM Proceedings ... @ $70 = ---------
($100 post Conference)

## SUMMARY

NOTE: All fees in Canadian dollars. Payments in US $ will be subject to exchange rate of: $1.50 Canadian = $1.00 US

Subtotal of all above fees: $ __________

7% GST (#870488889 RT): $ __________
(Canadian residents only)

Total Due: $ __________

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## METHOD OF PAYMENT

❑ AMEX ❑ MasterCard or ❑ VISA or
❑ Cheque (to Canadian Nuclear Society)

Name on credit card: ______________________________
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Card #: ______________________________

Expiry Date (yyyy/mm) _____/___

Signature (required for card payment):

______________________________ Date: __________

Please note Cancellation Policy: A fee of $100 will be charged for all cancellations received after 2001 May 11.

Société Nucléaire Canadienne
22ième Conférence annuelle
Hôtel Delta Chelsea, Toronto, Ontario
10-13 juin 2001

## FORMULAIRE D' INSCRIPTION

(Veuillez dactylographier ou écrire en caractères gras ou moulés)

Nom:_____________________________________________
(Dr./M./Ms.) prénom nom de famille

Titre:_____________________________________________

Affiliation: ________________________________________

Adresse au bureau:__________________________________
numéro nom de la rue

__________________________________________________
Ville Province/État

__________________________________________________
Code postal Pays

Numéro de téléphone au bureau:__________________________

Numéro de télécopieur:________________________________

Adresse électronique:_________________________________

Ferez-vous une présentation? ❑ Oui ❑ Non

Désirez-vous des repas végétariens? ❑ Oui ❑ Non

Ce formulaire d'inscription est également disponible au site web de la SNC : www.cns-snc.ca

Pour plus d'information sur la conférence, veuillez communiquer avec Denise Rouben, administratrice du bureau de la SNC, comme suit:
Tél: 416-977-7620
Télécopieur: 416-977-8131
Courriel: cns-snc@on.aibn.com.

Les réservations d'hôtel doivent être faites directement en communiquant avec le Delta Chelsea, au 416-243-5732 ou au 1-800-243-5732. Quand vous appelez le Chelsea, vous devez indiquer que la réservation est pour la Conférence annuelle de la SNC (code : GCMCNS). Un bloc de chambres est réservé pour la conférence jusqu'au 11 mai 2001. Le prix des chambres est de 189$ par nuit + taxes, simple ou double. Des chambres fumeur et non-fumeur sont disponibles.

*Pour l'usage du bureau:*

Membre SNC?
ID #:
Entré:
Traité:
Reçu envoyé:

## MODALITÉS D' INSCRIPTION

| Inscription: | Jusqu'au 11 mai | Après 11 mai |
|---|---|---|
| Membre SNC | 530.00$ ❑ | 600.00$ ❑ |
| Non-membre SNC | 595.00$ ❑ | 665.00$ ❑ |

(Inclut toutes séances SNC, une copie des comptes-rendus, la réception, les repas de la conférence y inclus le banquet)

| | | |
|---|---|---|
| Membre retraité SNC | 160.00$ ❑ | 200.00$ ❑ |
| Étudiant à plein temps | 160.00$ ❑ | 200.00$ ❑ |

(Inclut toutes séances SNC, une copie des comptes-rendus, la réception, les repas de la conférence y inclus le banquet)

Inscription d'un jour (Inclut les séances et les repas du jour: lunch lundi ou mercredi, le banquet mardi)
N'inclut pas les comptes-rendus sur CD-ROM.

| | | |
|---|---|---|
| Membre SNC | 280.00$ ❑ | 310.00$ ❑ |
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Invité(e) – gratuit (Inclut la réception seulement) ❑

Nom de l'invité(e): __________________________

Billets additionnels de lunch: ....@ 35$ = ______
Pour quel jour? ❑ Lundi ❑ Mercredi

Billets additionnels pour le banquet (mardi): ...@ 65$ = _____

Copies additionnelles des comptes-rendus sur CD-ROM (100$ après la conférence)...@ 70$ = _____

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Sous-total des frais ci-dessus: ___________$

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Veuillez noter que toute annulation après le 11 mai 2001 sera sujette à des frais d'administration de 100$.

# END POINT

## Nanuke of the North

*by Jeremy Whitlock*

*There are strange things done in the midnight sun,*
*By the men who moil for gold.*
*The arctic trails have their secret tales*
*That would make your blood run cold.*

*- Robert Service, from "The Cremation of Sam McGee"*

With all the hand-wringing over pollution and energy use, it's easy to forget that many communities in our own backyard burn diesel oil like, well, their lives depend on it. In the Canadian Arctic (translation for Torontonians: way north of Algonquin Park) diesel is King. In many regions it is burned for transportation, heating, and electricity – total dominance of the energy market.

While pampered southern minds reel at the thought of running diesel generators for anything but back-up power, locomotive-sized engines on the tundra operate year-round, 24 hours a day, seven days a week. The new territory of Nunavut consumes 33 million litres of diesel fuel a year for the production of electricity. Over one quarter of that (9 million litres) is used to run the capital of Iqaluit, located at the head of Frobisher Bay, Baffin Island.

But electricity, as every adult Canadian knows, is just the start. The 5,000 inhabitants of Iqaluit consume a further 20 million litres of diesel fuel each year for space heating, primarily by circulating water from household boilers (in some cases by forced-air furnaces).

Plans are on the horizon, however, to heat some larger buildings with cooling water from the town's three massive diesel generators. Clearly, one supposes, the creative minds entertaining these thoughts of cogeneration and centralization will turn, sooner or later, to the question of a better fuel source.

If ever there was a perfect application for nuclear energy, it is remote district heating (okay, perhaps second to military submarines). No other technology is as good at making hot water, particularly in remote regions. Its flexibility, zero emissions, and low fuel supply make it the cleanest, safest, and most efficient way to make a pot of tea, bar none.

Arctic dwellers, of course, have little time for the cleanest, safest, and most efficient way to keep themselves warm. At heavily subsidized diesel prices, few incentives exist to switch to other fuels, including uranium. And who knows – with predictions of Arctic ice melting due to global warming, the denizens of Iqaluit may even cast secret smiles upon the 100,000 (completely avoidable) tonnes of $CO_2$ they belch into the atmosphere each year.

But one must avoid jumping to conclusions. Atomic Energy of Canada Ltd. (AECL) was once active in the district-heating market, and perhaps the time is right to breathe new life into this program. Let's make Iqaluit, one of Canada's fastest growing communities and newest territorial capital, a model of environmentally sustainable frontier growth for the new millennium (spin doctors take note).

After all, the ground work is already there – it's a little-known fact that Iqaluit was once earmarked by the Diefenbaker government for a massive nuclear heating project. In the late Fifties a design existed for an enclosed dome around much of the community, heated by a nuclear reactor buried in a nearby hill. Sadly, the Treasury Board, not known for its nuclear vision, canned this project in favour of the more modest development in evidence there today.


We would have been forty years ahead of China, which recently announced innovative plans to heat its northeast city of Shenyang with two low-temperature 200MW reactors developed at Qinghua University.

Let us dust off AECL's Slowpoke Energy System, an in-ground pool reactor designed to supply 10,000 kW of hot water for space heating. This technology could be plugged into the existing heating system of most buildings in Iqaluit.

The reactor's inherently safe, low-temperature operation could be monitored by local engineers, much the same as diesel plants are today. A central nuclear engineering office could provide high-level technical support for several northern communities simultaneously.

Best of all, the plant would produce no emissions, and its tiny fuel load would be flown in once every three years. The summer shipment of diesel oil to Frobisher Bay would be a shadow of its former self.

AECL shopped its SES technology around Canada during the Eighties, and came close to installing one at the University of Saskatchewan, before deciding that the competition with fossil fuels wasn't worth the fight. With nuclear power you can't just be comparable in cost, you must be persuasively superior. (Surely the spiralling price of natural gas would sweeten the argument today?)

Another problem in remote regions is that electricity must still be generated, and it makes sense to use one fuel type. To this end, let's finish our development of the Nuclear Battery. These brilliant devices, explored by AECL in the Eighties, can be hooked to a Rankine-cycle engine to crank out 600 kW of electricity (about 200 homes' worth), or they can supply high-pressure steam. They are small, passively safe, and run for 15 years before needing replacement.

The coolant for the Nuclear Battery is based on heat-pipe technology that uses no moving parts (hence the "battery" spin). The fuel is based on TRISO coated uranium-dioxide particles – the same inherently safe concept at the heart of South Africa's new Pebble-Bed Modular Reactor (PBMR), seen by many as the future of the industry.

A bank of AECL-designed Nuclear Batteries would supply the heating and electrical needs of Iqaluit, at a cost comparable with diesel fuel.

If residents wish to go further and wean themselves off diesel transportation fuel, we can add a few more Batteries to electrolyze hydrogen from Frobisher Bay, and Ballard Power Systems would happily convert their vehicles. As a consumer of transportation, heating, and electrical generation fuel, Iqaluit would be virtually independent of the rest of Canada (and an icon of environmental sustainability for the world).

That kind of True North Strong and Free may be getting a bit ahead of ourselves, but it doesn't hurt to dream.

*Don't Miss*

## Nuclear Industry Winter Seminar

**March 26, 27, 2001**
**Ottawa, Ontario**

**The annual overview of the Canadian nuclear program by its leaders**

Contact: Lise Marshall
Canadian Nuclear Association
Ottawa, Ontario
Tel. 613-237-0640
Fax 613-237-0989
e-mail: marshalll@cna.ca
Web site: www.cna.ca

***Last chance***

## Call for Nominations CNS Council

If you know of someone who would be a good member of the CNS Council or if you are interested yourself, contact NOW

V.S. (Krish) Krishnan
CNS Past President
Atomic Energy of Canada Limited
2251 Speakman Drive
Mississauga, Ontario L5K 1B2
Telephone: 905-823-9060, Ext. 4555
Email: krishnanv@aecl.ca

## 2001

**March 26, 27**
**Nuclear Industry Winter Seminar**
Ottawa, Ontario
Contact: Lise Marshall
CNA
Tel. 613-237-0640
Fax 613-237-0989
e-mail: marshalll@cna.ca

**April 8 - 12**
**ICONE-9 9th Int. Conf. on Nuclear Engineering**
Nice, France
Visit website: www.sfen.fr/icone9

**April 25 - 27**
**CANDU Reactor Safety Course**
Mississauga, Ontario
Contact: Denise Rouben
CNS
Tel. 416-977-7620
Fax 416-977-8131
e-mail: cns-snc@on,aibn.com

**April 29 - May 3**
**9th International High Level Radioactive Waste Management Confeence**
Las Vegas, Nevada
Contact: American Nuclear Society
Tel: 708-352-6611
e-mail: meetings@ans.org

**May 13 -17**
**CRPA / CRSO Annual Conference**
Halifax, Nova Scotia
Contact: Dr. George Mawko
e-mail: gmawkp@is.dal.ca

**June 10 - 13**
**22nd CNS Annual Conference**
Toronto, Ontario
Contact: Denise Rouben
CNS office
Tel: 416-977-7620
e-mail: cns-snc@on.aibn.com

**June 17 - 21**
**ANS Annual Meeting**
Milwaukee, Wis
Visit website: www.ans.org

**Sept. 9 - 13**
**Global 2001 Conference: "Back End of the Fuel Cycle - From Research to Solutions"**
Paris, France
Contact: SFEN/global2001
e-mail: global2001@sfen.fr

**Sept. 9 - 14**
**2nd International Conference on Inertial Fusion Sciences and Applications**
Kyoto, Japan
Contact: Dr. William Hogan
Lawrence Livermore
National Laboratory
Livermore, California
Tel: 925-422-1344
e-mail: bill-hogan@llnl.gov

**Sept. 24 - 27**
**7th International Conference on CANDU Fuel**
Kingston, Ontario
Contact: Prof. Brent Lewis
Royal Military College
Tel: 613-541-6611
e-mail: lewis-b@rmc.ca

**Sept. 30 - Oct. 4**
**ICEM'01 - 8th International Conference on Radioactive Waste Managment and Environmental Remediation**
Bruges, Belgium
Contact: Donna McComb
Laser Options Inc.
Tucson, Arizona
Tel. 520-292-5652
e-mail: dmccomb@laser-options.com
Web: www.icemconf.com

**Oct. 3 - 5**
**Climate Change: Canadian Technologies Development**
Toronto, Ontario
Contact: Duane Pendergast
Comutare
Tel; 403-328-1804
e-mail:
duane.pendergast@computare.org

**Nov. ??**
**Management of System Ageing**
Toronto, Ontario
Contact: Robert Tapping
AECL - CRL
Tel: 613-584-8811 ext 3219
e-mail: tappingr@aecl.ca

**Nov. 11 - 15**
**ANS Winter Meeting**
Reno, Nevada
Contact: ANS
LaGrange Park, Illinois
Tel. 708-352-6611
e-mail: meetings@ans.org

**Nov. 11 - 16** **6th International Conference on Tritium Science and Technology**
Tsukuba-shi, Ibaraki-ken, Japan
Contact: Dr. M. Nishi
Japan Atomic Energy Research Institute
Tel. +81-29-282-6390
e-mail: nishi@tpl.tokai.jaeri.go.jp

## 2002

**March 10 - 14** **4th International Conference on Isotopes**
Cape Town, South Africa
Contact: 4ICI Conference Secretariat
Claremont, South Africa
Tel. +27-21-762-8600
e-mail: 4ici@globalconf.co.za
Web: www.globalconf.co.za

**May 6 - 9** **Steam Generator and Heat Exchanger Conference**
Toronto, Ontario
Contact: Robert Tapping
Tel: 613-584-8811 ext 3219
e-mail: tappingr@aecl.ca

**June 17 - 21** **ANS Annual Meeting**
Hollywood, Florida
Contact: ANS
LaGrange Park, Illinois
Tel. 708-352-6611
e-mail: meetings@ans.org

**June ??** **23rd CNS Annual Conference**
Toronto, Ontario
Contact: CNS office
Toronto, Ontario
Tel. 416-977-7620
e-mail: cns-snc@on.aibn.com

**July ??** **Symposium on the Isolation of Radioactive Waste**
Toronto, Ontario
Contact: Judy Tamm
AECL - SP
Tel. 905-823-9060 ext. 4197
e-mail: tammj@aecl.ca

**Oct. 7 - 10** **PHYSOR-2002: International Conference on the New Frontiers of Nuclear Technology - Reactor Physics, Safety and High-Performance Computing**
Seoul, Korea
Contact: Prof. Nam Zin Cho
KAIST
Taejon, Korea
Tel. +82-42-869-3819
e-mail: tpc@physor2002.kaist.ac.kr

**Oct. 21 - 25** **PBNC 2002 - 13th Pacific Basin Nuclear Conference**
Shenzhen, China
Contact: PBNC 2002 Secretariat
Fax: +86-10-6852-7188
e-mail: cns@cnnc.com.cn

*Can you guess what conference the above photograph is from?*

# Index ~ Canadian Nuclear Society Bulletin

*(Our thanks to Morgan Brown for compiling an index of the CNS Bulletin over the past ten years. For publication we have edited his complete index (which is on the CNS Web site) , concentrating only on major articles or papers. For various reasons not every volume had four issues, as indicated below. This issue includes Volumes 12 to 17. Volumes 18-22 will be printed in a following issue.*

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| Vol. 13, | 1992 | 4 issues | Vol. 18 | 1997 | 3 issues |
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# 2000-2001 CNS Council • Conseil de la SNC

## Executive / *Exécutif*

| | | |
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