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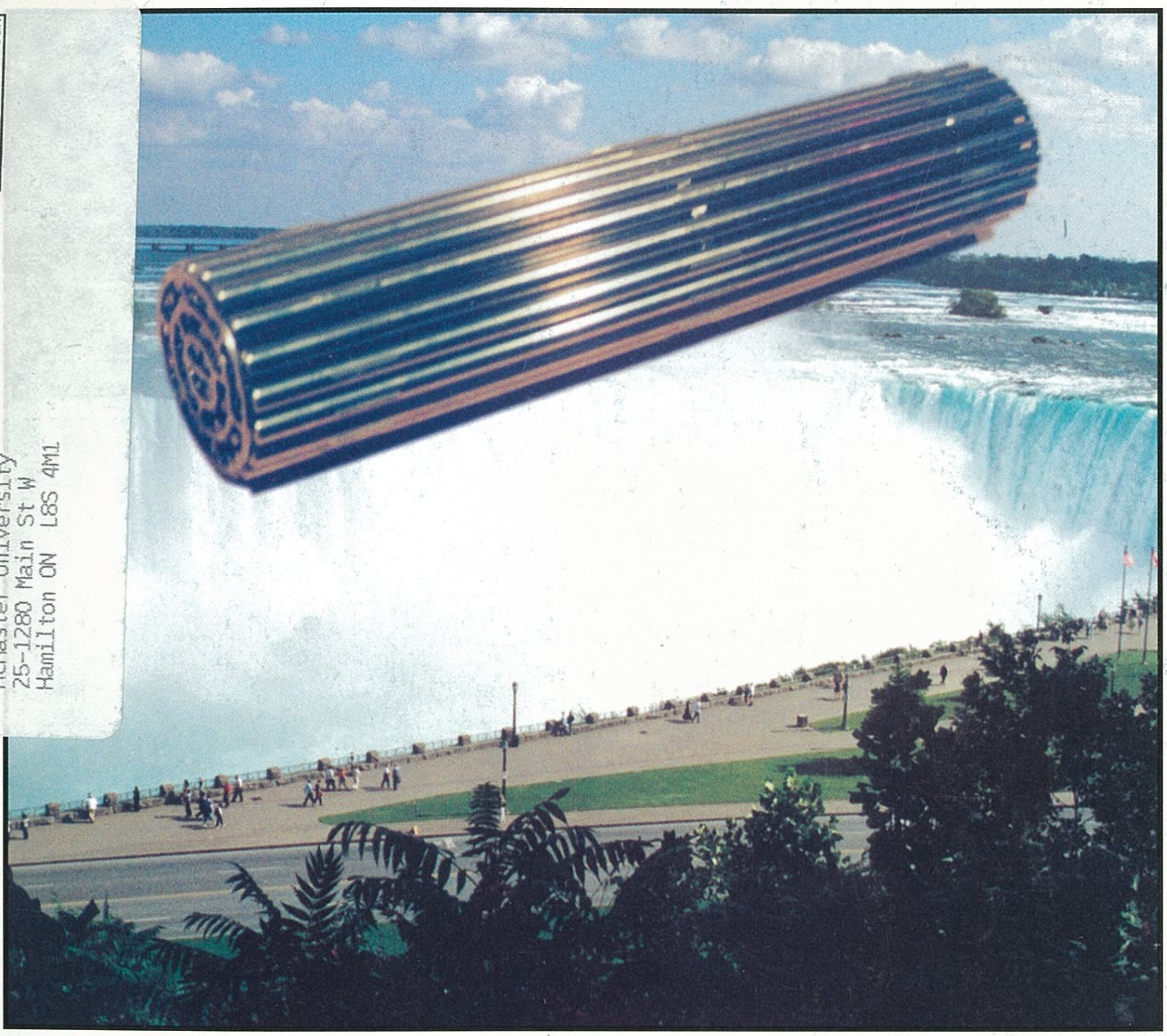

- Conference Reports
  - CANDU Fuel
  - Future of Nuclear
  - Isotopes
- Canadian CANDU Fuel Program
- Regulatory View of Lay-up
- Fuel Waste Update

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Cover Illustration

The illustration on the cover of this issue is our attempt at being artistic to symbolize the two major, non green-house-gas, sources of electricity, hydraulic and nuclear; inspired by the CANDU Fuel Conference in Niagara Falls.

CANADIAN NUCLEAR SOCIETY

bulletin

DE LA SOCIÉTÉ NUCLÉAIRE CANADIENNE

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

CNS provides Canadians interested in nuclear energy with a forum for technical discussion. For membership information, contact the CNS office, a member of the Council, or local branch executive.
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La SNC procure aux Canadiens intéressés à l'énergie nucléaire un forum où ilf peuvent participer à des discussions de nature technique. Pour tous renseignements concerant les inscriptions, veuillez bein entrer en contact avec le bureau de la SNC, les membres du Counseil ou les responsables locaux. La cotisation annuelle est de 60.00$, 35.00$ pour les retaités, et 20.00$ pour les étudiants.

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Leadership ?

From our (worm's eye ?) view, an element that has been sadly lacking in our Canadian nuclear program over the past few years is leadership.

This sense was enhanced at the recent conference on the future of nuclear energy in Canada where the many issues and challenges facing the nuclear program were noted but no clear approach for dealing with the issues or overcoming the challenges were presented.

Each organization appears to be going its own way, concerned with only its particular interest and only for the immediate future. This may be the "market" approach that is so much in vogue these days but it leads to a myopic and self-centred viewpoint.

Paradoxically, some of the most cogent remarks have been coming from our chief regulator, AECB president Agnes Bishop. In recent speeches, and even in the AECB's Annual Report, she poses some fundamental questions. What about the research and development necessary not only for safety but to maintain the industry and to move it forward ? There are few young people in the nuclear program - where are the next generation of nuclear scientists, engineers and technicians to come from ? What about the credibility of the nuclear industry in the eyes of the public ?

None of these questions are being addressed by those in charge of our major nuclear organizations. Funds for research and development have been slashed. The head of our largest nuclear utility has been quoted as saying his company would only support R & D which addressed "current or anticipated plant operational and safety needs". With such a short-sighted approach it is highly likely that when the next major problem arises (such as pressure tube failures of a few years ago) there will be no scientific capability to deal with it.

As for youth, the nuclear industry has shown little interest in any programs to interest young people in nuclear science and technology. With its limited resources the CNS has sponsored summer courses for high school science teachers, but there has been very little support from industry.

And credibility ? This is, admittedly a difficult challenge. But, at least the industry could be trying to tell its story. Where is the communication plan let alone program ?

Leadership does not have to be by an individual. OPG president Ron Osborne recently called for a "renewal" of the collaboration and partnership between governments and industry that marked the early growth period of the Canadian nuclear program. Perhaps it should be encouraging that someone in his position recognizes that need, but, there is little sign of any movement towards such cooperation. Will it take the chief regulator to mandate it ?

Fred Boyd

IN THIS ISSUE

To our great pleasure and, we hope, your interest and enjoyment, in this issue we have several submissions from readers in the form of letters, comments, and viewpoints.. However, these are not all in one place. The **Letters** are on page 2. Two are on that seemingly perpetual topic of the Linear No-Threshold (LNT) hypothesis for radiation protection. A third letter is a critical comment on the Atomic Energy Control Board from someone who has seen both sides, as an AECB project officer and as a technical engineer for utilities. And the fourth is seeking help in retaining our scientific history.

A note from one of the authors clarifying a point in the CANFLEX paper in the last issue is placed with the other articles on CANDU fuel. The paper, **Fusion Research Demise in Canada,** is really more of a pointed comment from Richard Bolton than a technical paper, even though it was originally presented at the CNS 1999 Annual Conference. Then, placed at the back, is a Viewpoint by Jeremy Whitlock, accompanied by its own editorial cartoon.

The body of this issue is devoted to two recent conferences, the **6th International Conference on CANDU Fuel,** and a **Conference on the Future of Nuclear Energy in Canada.** There are reports on each of these along with selected papers.

From the fuel conference there is the overview paper, **The Canadian CANDU Fuel Development Program and Recent Fuel Operating Experience,** and one of the historical reviews, **CANDU Fuel: Design-/Manufacturing Interaction.** From the futures conference, there is also an overview paper, **The Future of Nuclear Energy in Canada: An Overview,** and a status report on the fuel waste question, **Nuclear Fuel Waste Policy in Canada.** In the context of the future of the Bruce "A" plant we have a paper on **Regulatory Considerations of the Lay-Up of Power Reactors.** Finally, there is a brief report on the **3rd International Isotope Conference** which was held in Vancouver, to highlight that important segment of nuclear activities.

There is the usual relatively short section on **General News** with items you may not have seen elsewhere, and a fairly extensive section on **CNS News,** reflecting the active nature of the Society. Also, please note our advertisers.

As always we thank our contributors and the authors who have permitted us to reprint their papers. Your comments, viewpoints, opinions, are always welcomed.

Use of LNT for regulation disputed

In his letter in the July 1999 CNS Bulletin and its Reference 1, Richard Osborne states *"one must distinguish between the practice of radiation protection and the science of radiation protection"* and goes on to claim that, even if the science does not support a linear-no threshold (LNT) model, we should continue to use LNT for regulation because it is the most practical and prudent approach. My purpose here is to dispute that conclusion.

The alternative to this radiation-LNT approach is to treat radiation as we treat chemical pollutants. Using air pollution as an example, we limit concentrations of SO_2, nitrogen oxides, particulates, ozone, etc. Osborne says that this is equivalent to assuming that dose rate, rather than integrated dose determines the risk —a rather different scientific model— but that is a misinterpretation. For example, air pollution regulations limit the number of days per year that specified pollution levels can be exceeded (for radiation, one might place limits on number of monthly exposures per year, or per 5 years, that can exceed some specified limit). Air pollution regulations are designed largely to make them practical to implement. They are a very crude way of limiting exposures without being specific about whether the important risk parameter is dose rate, total dose with or without a threshold. But crude as it is, its crudeness is consistent with the crudeness of our scientific understanding.

Using LNT for regulating radiation is clearly a more elegant and quantitative approach, much less crude than the air pollution method. But that does not mean that it is better; the problem is that it is **not** consistent with the crudeness of our scientific understanding. The fact that it is more quantitative is a deceptive veneer of false pretense, hiding the fact that it has no scientific basis (and even runs counter to the bulk of available scientific evidence). Osborne claims that it is "prudent", but prudence is best judged by the results achieved. Let's compare our two alternatives on that basis.

The air pollution regulations, crude as they are, prevent catastrophes like the 1930 Meuse Valley, the 1948 Donora (Pennsylvania), and the 1952 London incidents, and they generally avoid identifiable deaths. Most importantly, they give the public confidence that it is being protected. The Mayor of Pittsburgh goes to great lengths to attract new industries, so long as they comply even marginally with air pollution regulations, and the Pittsburgh public, which is highly sensitized to air pollution problems, supports him on this. The Media give scant attention to studies indicating that tens of thousands of Americans die prematurely each year from air pollution; the public assumes that this is caused by violations of regulatory limits, although there is little evidence for such an interpretation.

How unsatisfactory is this situation? It allows our technology to progress and to increase Society's wealth, and technology and wealth create health, far outstripping the harm to health done by the pollution. Air pollution may reduce our life expectancy by something like 30 days, whereas technology and the wealth it has created have increased our life expectancy by 30 years in this century, and they are continuing to increase our life expectancy by something like 30 more days every year.

For comparison with this air pollution approach, how well has the radiation-LNT approach to regulation worked? For every little bit of radiation, we calculate the number of deaths, and killing is something the Media are quick to report. People are moved by such reports and view these deaths as real, perhaps even afflicting themselves or their loved ones. The public has thus been driven insane over fear of radiation, losing all contact with reality. As a result, we have largely lost the benefits of nuclear power which could be averting tens of thousands of deaths per year from air pollution. We are losing many other benefits of radiation such as food irradiation which could be averting millions of cases of food poisoning, saving thousands of lives, each year. We are wasting our Society's wealth on ridiculous clean-up programs at nuclear facilities; this wasted wealth could save thousands of lives each year if it were spent on biomedical research, on public health programs, or on highway safety.

In the light of these comparisons between the results of the air pollution vs the radiation-LNT approaches to regulation, which is the more prudent?

Bernard L. Cohen
Physics Dept.
University of Pittsburgh

Controversy over beneficial effects of ionizing radiation - another ugly fact

Thank you for including the abstract and conclusions of my WONUC paper[1] in the July issue of the *CNS Bulletin.*[2]

When I think about the linear no-threshold (LNT) hypothesis of radiation carcinogenesis, I am reminded of the famous quotation: *"The great tragedy of science is the slaying of a beautiful hypothesis by an ugly fact."*[3] How can we not perceive the very strong political, social and economic issues, which override the scientific considerations, when we try to understand why the LNT hypothesis continues to be an exception to this fundamental requirement of science?

The University of Birmingham study of radioiodine treatment of hyperthyroidism, recently published in The Lancet,[4] provides yet another of the hundreds of ugly facts that contradict the LNT hypothesis. This study of 7414 adult patients, treated in Birmingham UK between 1950 and 1991 with a mean cumulative dose of 308 MBq of iodine-131, identified 638 cancer diagnoses and 448 cancer deaths in 1971-91 among the treated patients. This was compared with National Statistics data on cancer incidence and mortality for England and Wales, specific for age, sex and period: 761 and 499. The standardized incidence ratio is 0.83 [95% confidence interval 0.77-0.90] and the standardized mortality ratio is 0.90 [0.82-0.98]. The scientists concluded, "The decrease in overall cancer incidence and mortality in those treated for hyperthyroidism with radioiodine is reassuring."

It certainly is reassuring when we realize that a dose of 308 MBq corresponds to 50,000 rem to the thyroid and 28 rem to the whole body.[5] This is more than ten times the average dose of 15 mSv (or 1.5 rem) received by the evacuees from the 30-km zone around the Chernobyl disaster.[6]

So why is this important? When we realize how fearful people are of cancer and how they associate every nuclear activity and incident with their likelihood of getting a cancer, we ought to be concerned. I just can't get over the irony of this situation. We design and operate our reactors to keep the likelihood of a severe accident below once in a million years. Then I realize that if this hypothetical event actually did occur, no one outside the plant would be injured. In fact their exposure would likely be beneficial!

Prominent scientists are coming, early in November, to attend a meeting of the Scientific Advisory Board of the International Centre for Low Dose Radiation Research at the University of Ottawa. Prof. Tubiana of the French Academy of Sciences and Prof. Sakamoto, Director, Tohoku Radiological Science Centre in Japan will be giving lectures at hospitals in Ottawa and Toronto and at CNS branch meetings. They will also try to initiate a program of international cooperation between Japan and Canada to replicate some of the Japanese research and treatments to cure cancers with low doses of radiation. Hopefully there will be a positive response from Canadian medical scientists.

Will these medical applications change attitudes of Canadians about the real health effects of low doses of radiation? If not, what will?

Jerry Cuttler

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1. Cuttler JM, "Resolving the controversy over beneficial effects of ionizing radiation," Proceedings of Conference on the Effects of Low and Very Low Doses of Ionizing Radiation on Health, Versailles, France, 1999 June 16-18, World Council of Nuclear Workers, 49 rue Lauriston, 75116 Paris, Report AECL-12046.
2. CNS Bulletin 20, No. 2, 1999 July, pp 40.
3. Huxley TH (1825-95), "Collected Essays 1893-94 Biogenesis and Abiogenesis."
4. Franklyn JA, Maisonneuve P, Sheppard M, Betteridge J and Boyle P, "Cancer incidence and mortality after radioiodine treatment for hyperthyroidism: a population-based cohort study," The Lancet 353, 1999 June 19, pp 2111.
5. Eisenbud M, "Environmental Radioactivity, 2nd Edition," Academic Press, New York, 1973, pp 421-425.
6. "Chernobyl - ten years on: radiological and health impact," an appraisal by the NEA Committee on Radiation Protection and Public Health, Nuclear Energy Agency, Organisation for Economic Co-operation and Development, 1995 November, pp 47.

(See additional letter, page 60)

Safety frustrated by AECB

Two articles in your July 1999 issue were of particular interest to me.

The first was the article by Gordon Brooks where he kindly credits me with a role in initiating SDMs. The second was the article by Dr. Agnes Bishop [President of the Atomic Energy Control Board] undertaking to perform regulatory functions in a more open and transparent fashion.

I was struck by the linkage between these articles, and I recalled how our early work on SDMs [safety design matrices] was frustrated by the actions of the AECB and particularly by the closed and opaque approach they then used.

The early work identified many actions required by operators to ensure safety. These were communicated to the AECB and the actions adopted in station procedures. Unfortunately, the operator licensing group within the AECB did not agree with many of these actions. Rather than resolve their concerns by approved procedures, the AECB examiners forced their perceptions on stations via "model" answers to examination questions. Many of these answers were technically wrong and were dangerous. Ontario Hydro, in the interests of getting their candidates through examinations trained them on AECB answers which the trainers recognized as dangerous.

In 1988 I communicated my concerns to the AECB. They invited me to submit a safety representation, which they would consider under their prescribed process called R76. This had the openness and transparency that Dr. Bishop is now reaching for. It called for a resolution of the submission by technical debate in the public arena.

I made this submission with the cooperation of Bruce A management, illustrating my concerns using a recent Bruce A examination. The AECB [staff] responded by saying that they would not use the required process of R76, but would use an internal hearing, shielded from public view, which would not permit technical discussion.

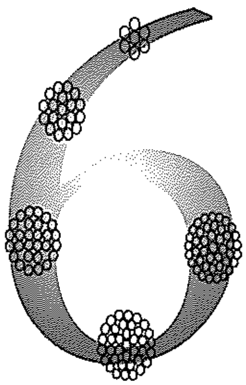
Despite the inadequacies of the process, the hearing identified that all the answers in the examination were dangerous. The AECB asked Ontario Hydro informally to stop using these "model" answers to train examination candidates. This request was "discreet" and the AECB said they could not make a formal request as they would be embarrassed as a result. It was pointed out to them that, without a formal request, the response would still leave safety concerns, e.g. the implications for other stations, and the concern about candidates who had "passed" by using answers now known to be dangerous. The AECB replied that they would not take any further actions as they would "affect the credibility of the AECB."

In 1997 I again made a safety representation to the AECB. This related to the shutdown of units in Ontario due to an inadequate safety culture. My representation showed that the [inadequate] culture within Ontario Hydro had arisen because of improper actions by the AECB of the sort I have already illustrated. I showed that the industry could not make a turnabout until the AECB committed to do the same.

Declan Whelan

Declan Whelan is currently on the staff of the Point Lepreau station. Previously he was with Ontario Hydro and earlier was AECB Project Officer at the Bruce 'A' Station.

6th International Conference on CANDU Fuel



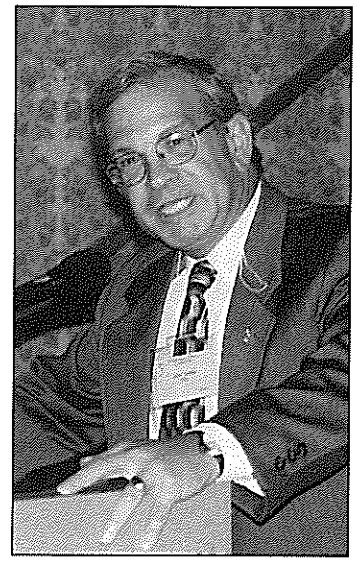
"Symbol of Conference"

Fuel for the Next Millennium was the theme for the sixth conference on fuel for CANDU reactors, held in Niagara Falls, Ontario, September 26 to 30, 1999.

With about a third of the 120 delegates coming from outside Canada this was truly an "international" meeting. Perhaps the choice of Niagara Falls, the top tourist site in Canada, helped attract the many foreign attendees but the excellent program and arrangements kept all delegates at the conference until the final sessions.

The program involved 70 papers presented in 15 sessions. Except for the opening plenary session on the first day there were two, or occasionally three, parallel sessions to accommodate the number of papers. The overall thrust was that the performance of CANDU fuel has been excellent but there is a need to look forward.

The plenary session on the first morning included six papers giving overviews from the countries operating CANDU type nuclear power plants; Argentina, India, Korea, Pakistan, Romania and Canada. Each of the countries have established their own fuel manufacturing capability (inmost cases enabled through technical transfers from Canada). The paper from India outlined their unique experience in having had to develop their own processes over the past two decades. In contrast the Korean ongoing CANDU fuel development program has been conducted largely in cooperation with Canada, especially on CANFLEX and DUPIC fuel designs.



Jerry Cuttler

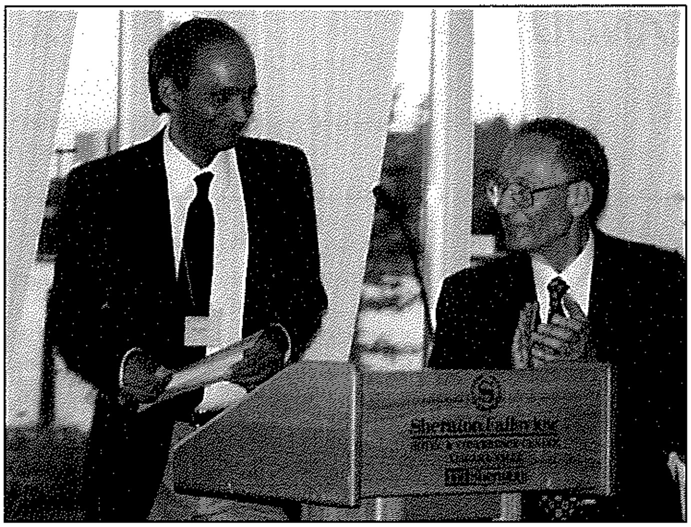
Delegates to the 6th International Conference on CANDU Fuel, in Niagara Falls, September 26 to 29, 1999, start to pose for the official group photograph. (The photographer was on the balcony above.)

The Korean overview paper emphasized the potential synergism between their PWR and CANDU programs, which has influenced their work on MOX, RU (recovered uranium), DUPIC and TANDEM (reprocessed PWR fuel). Because of their concern about proliferation, Korea is favouring RU, using uranium from foreign reprocessing plants, as well as the use of SEU (slightly enriched uranium) for its CANDU plants. A later Korean speaker commented that their utility (KEPCO) considered the DUPIC fuel cycle too expensive due to its high handling costs. Another Korean speaker, from KINS, the regulatory authority, commented that although considerable work had been done on CANFLEX fuel the design was not yet approved, at least partly due to new stringent Korean regulations. The plenary speaker from Argentina indicated that they were developing a common fuel for their two different plants (Embalse and CORDOBA).

(The paper by Joseph Lau et al on the Canadian scene is reprinted in this issue of the *CNS Bulletin*.)

The titles of the remaining technical sessions provide an indication of the scope of the papers and discussion at the conference.

- CANFLEX Fuel Design and Development



CNS President Krish Krishnan and Conference chairman Roman Sejnoha share a moment during the opening reception of the 6th International Conference on CANDU Fuel in Niagara Falls, September 26, 1999.

- Fuel Management
- Fuel Handling
- Fuel Performance Assessment
- Fuel Safety
- Manufacturing and Quality Assurance
- Advanced Fuel Cycles

A few selected abstracts are reprinted in this issue of the *CNS Bulletin* to provide a flavour of the conference. Full Proceedings, in two volumes, will be available from the CNS office.

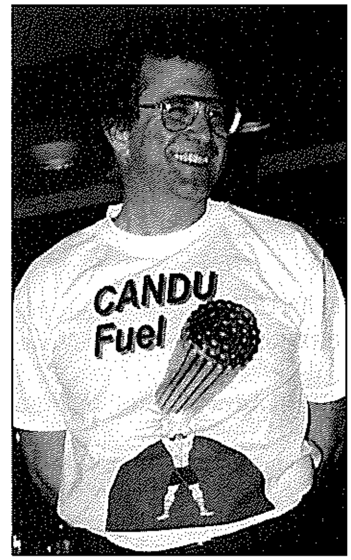
As a deliberate step towards saving "corporate memory" a special session was devoted to "history". Three veterans of the CANDU fuel program presented their personal views of various aspects of the development of CANDU fuel:

- Ron Page on *Looking Back at Fuel Thirty Nine to Forty Years Ago*
- Norm Graham on *CANDU Fuel: Design / Manufacturing Interactions*
- Brian Cox on *Oxidation and Hydriding of Zirxaloy Fuel Cladding - the Inside (& Outside) Story*

(Norm Grahman's paper is reprinted in this issue of the *CNS Bulletin.*)

The conference opened with a reception on the Sunday evening which included a slide presentation on Niagara Falls and area by Hans Tammemagi, onetime at Whiteshell Laboratories, now a consultant and author living in St. Catherines. Among his books are a popular guide to the Niagara region and an introduction to nuclear science and technology to be published this winter.

At the luncheon on the Monday, former CNS president Jerry Cuttler gave one of his impassioned talks on the fallacy of the "linear, no-threshold, hypothesis" for radiation effects, in a presentation entitled, *Resolving the Controversy over Beneficial Effects of Ionizing Radiation.*



Peter Boczar shows off the special T-shirt he revealed during his animated talk to delegates at the 6th International Conference on CANDU Fuel, in Niagara Falls, September 28, 1999.

A conference banquet was held in the historic Victoria Park restaurant near the falls. Following the excellent buffet, delegates and their guests were entertained and inspired by Peter Boczar who gave an animated talk on, *CANDU: Fuel for the Next Millennium.* "If CANDU fuel is not a problem how can it be a solution", he asked rhetorically, then pointed out that the competition to CANDU is not nuclear but natural gas and, therefore, costs must be reduced. He suggested several advanced fuelling schemes which, he said, could increase power, increase burnup, and decrease waste. He closed with a ringing, "The world needs energy, the world needs nuclear, the world needs CANDU", and received a standing ovation.

Following the banquet delegates were invited to see the huge search lights which illuminate the falls and to choose the colours.

With very ample continental breakfasts and full buffet lunches (in addition to the banquet) it is likely that most delegates went home a few kilograms heavier.

The planning and execution of this conference once more demonstrated that Canadians (especially members of the Canadian Nuclear Society) are among the world's best conference organizers. One of the accomplishments of the organizing team was to obtain a number of corporate sponsors which enabled such a conference to be held while maintaining fees at a reasonable level.

The sponsors were: Canadian Nuclear Society; Atomic Energy of Canada Limited, CANDU Owners Group, Zircatec Precision Industries Inc. GE Canada Nuclear Products, Cameco, Stern Laboratories Inc, New Brunswick Power, Hydro Quebec. In addition, the International Atomic Energy Agency provided support for some of the delegates.

On the Thursday following the close of the conference delegates were offered tours of either Stern Laboratories in Hamilton or the Darlington NGS.

The Organizing Committee included: Roman Sejnoha (chairman), Corneliu Manu, Parva Alavi, Mukesh Tayal, Paul Chan, Zoran Bilanovic, Alan Manzer, Peter Purdy, Fernando Doria, Pamela Tume, Steve Palleck, Bernie Surette, and, from the CNS office, Sylvie Caron and Zanna Panton.

6th International Conference on CANDU Fuel
List of papers

PLENARY SESSION 1: International Experience and Programs

PHWR Fuel Demand and Manufacturing Program in India
C. Ganguly

PHWR Advanced Fuel R&D for the 21st Century in Korea
H.C. Suk

Romanian Nuclear Program - Status and Perspective
A. Pascu and A.C. Galeriu

Nuclear Fuel Cycle Activities in Argentina
P. Adelfang

Pakistan: Experience in CANDU Fuel for KANUPP and Establishment of Supporting Facilities for Self Reliance
M. Shabbir

Canadian CANDU Fuel Development Program and Recent Operating Experience
J.H. Lau, W.W. Inch, D.S. Cox, R.G. Steed, E. Kohn and N.N. Macici

SESSION 2A: CANFLEX® Fuel Design and Development

Demonstration Irradiation at Point Lepreau: A Status Update
R.A. Gibb, R.W. Sancton, R.G. Steed, P.J. Reid and J. Bullerwell.

CANFLEX- NU Fuel Licensing Status and Issues in Korea
G.S. Auh, J.S. Park, S.W. Woo and Y.H. Ryu.

Full Scale Water CHF Testing of the CANFLEX Bundle
G.R. Dimmick, W.W. Inch, J.S. Jun, H.C. Suk, G.I. Hadaller, R. Fortman and R. Hayes.

Critical Heat Flux and Pressure Drop for a CANFLEX Bundle String Inside an Axially Non-Uniform Flow Channel
L.K. Leung, D.C. Groeneveld, G.R. Dimmick, D.E. Bullock, and W.W. Inch.

An Update on the Design Verification of CANFLEX Fuel Bundle
P.K. Chan, P. Alavi, G.G. Chassie, J.H. Lau, P.L. Purdy, D. Rattan, R. Sejnoha, M. Tayal, B. Wong and Z. Xu.

Comparative Strength Assessment Between 43 and 37-element Fuel Bundles
G.G. Chassie, C. Manu and M. Tayal.

Static Strength Analysis of CANFLEX Fuel Bundle for CANDU-6 Reactor
M.S. Cho, K.S. Sim, H.C. Suk and S.K. Chang.

SESSION 2B: Fuel Management

Fuel Re-ordering in the Bruce A Reactor Cores
E. Kohn, J, Novak, H. Bromfield and R. Day.

Validation of WIMS-AECL with ENDF/B-V Against Phase B Reactor Physics Tests at Wolsong Units 2 and 3
I.S. Hong, C.H. Kim, B.J. Min, H.C. Suk and B.G. Kim.

Analysis of Xenon Spatial Oscillation in a CANDU 6 Reactor with DUPIC Fuel
C.J. Jeong and H.B. Choi.

Advanced CANDU Reactors Fuel Analysis Through Optimal Fuel Management at Approach to Refuelling Equilibrium
C.P. Tingle and H.W. Bonin.

SESSION 2C: Fuel Handling

New Fuel Bundle Packaging
J.W. Spencley and D.J. Semple.

High Polymer-Based Composites for Spent Nuclear Fuel Disposal Containers
H.W. Bonin and V.T. Bui.

Corrosion Resistance of (Th,U)O2 Fuel in Water
S. Sunder.

SESSION 3A: Fuel Performance Assessment

Assessment of Core Flow Pattern and Pressure Tube Creep at Cernavoda Unit 1
N. Mazalu.

Post-Irradiation Examination of Two Gentilly-2 Bundles to Investigate the Effect of Pressure Tube Diametral Creep on Fuel Performance
Z. He and M.R. Floyd.

Hydrogen gas in CANDU Fuel Elements
R. Sejnoha.

Measurement of the Composition of Noble-Metal Particles in High-Burnup CANDU Fuel by Wavelength Dispersive X-Ray Microanalysis
W.H. Hocking and F.J.Szostak.

Microacoustic Techniques to Assess the Local Characteristics of Irradiated Fuel Materials
B. Cros, D. Baron and V. Roque.

SESSION 3B: .Fuel Safety - Part I

Uprating Potential of a CANDU 6 Reactor with CANFLEX Fuel - A Safety Analysis Perspective
A. Grace and Z. Bilanovic.

Source Term Analysis for a Nuclear Submarine Accident
B.J. Lewis and J.J.Hugron.

Power Coefficient Calculation of a CANDU Reactor
H.B. Choi and J.W. Park.

Verification and Uncertainty Analysis of Fuel Codes Using Distributed Computing
D. Evens and R. Rock.

Verification of Fuel Performance Simulation Codes: Application of Distributed Computing
Y. Liu and C.J. Westbye.

SESSION 3C: Manufacturing and Quality Assurance - Part I

Implementation of CANFLEX Bundle Manufacture
A. Pant.

Five Years of Successful CANDU-6 Fuel Manufacturing in Romania
A.C. Galeriu, A. Pascu, G. Andrei and A. Bailescu.

Performance of Indigenous Resistance Welding Equipment for PHWR Fuel Fabrication , NFC Experience
G.V. Hemantha Rao, R.N. Jayaraj, M.S. Prakash, U.C. Gupta and C. Ganguly.

Approaching Six Sigma Quality in Nuclear Fuel Fabrication - An Indian Perspective
B. Laxminarayana, B.K. Kumar, N. Saratchandran and C. Ganguly.

Trends in Joining Technology Development for PHWR Fuel Assemblies in India
P.B. Desai and P.G. Kulkarni.

SESSION 4A: Advanced Fuel Cycles

Improvements in Argentine Operating NPPs and their Fuel Cycle
C. Notari and R. Corcuera.

SEU Fuel In Atucha-1 NPP, A Valuable Experience for a CANDU-6 Core Enrichment
L. Alvarez, J. Casario, J. Fink, R. Perez and M. Higa.

A Study on the Core Characteristics for a CANDU 6 Reactor Fuelled with Recovered-Uranium CANFLEX Bundles
B.J. Min, C.J. Jeong and H.C. Suk.

The Use of Stainless Steel in CANDU Fuel with Recovered Uranium
B.J. Min and H.C. Suk.

A Reactor Physics Study of the Economic Penalty Associated with LVRF and Increased Pressure Tube Thickness
D. Rozon and W. Shen.

Proliferation Hardening of Thorium Fusion Breeders with CANDU Spent Fuel
S. Sahin, H. Yapici, H.M. Sahin and V. Ozceyhan.

SESSION 4B: Fuel Safety - Part II

Status of SOPHAEROS Fission-Product Transport Code Validation
S. Gingras, R.S. Dickson and L.W. Dickson.

Release of Fission Products from CANDU Fuel in Air, Steam and Argon Atmospheres at 1500-1900_C: The HCE3 Experiment
R.D. Barrand, R.S. Dickson, R.S. Liu and D.D. Semeniuk.

Post-Irradiation Examination Results from the BTF-105A LOCA/LOECC Test
P.J. Valliant, J.D. Irish and S.T. Craig.

Preliminary Fission-Product and Post-Irradiation Examination Results from BTF-105B LOCA/LOECC Test
J.D. Irish, S.T. Craig and P.J. Valliant.

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The Canadian CANDU Fuel Development Program and Recent Fuel Operating Experience

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***Ed. Note:** The following paper was presented in the opening plenary session of the 6th International Conference on CANDU Fuel, held in Niagara Falls, Ontario, September 1999.*

Abstract

This paper reviews the performance of the CANDU fuel in the Canadian CANDU reactors in 1997 and 1998. The operating experience demonstrates that the CANDU fuel has performed very well. Over the two-year period, the fuel-bundle defect rate for all bundles irradiated in the Canadian CANDU reactors has remained very low, at between 0.006% to 0.016%. On a fuel element basis, this represents an element defect rate of less than about 0.0005%.

One of the reasons for the good fuel performance is the support provided by the Canadian fuel research and development programs. These programs address operational issues and provide evolutionary improvements to the fuel products. The programs consist of the Fuel Technology Program, funded by the CANDU Owners Group, and the Advanced Fuel and Fuel Cycles Technology Program, funded by Atomic Energy of Canada Ltd. These two programs, which have been in place for many years, complement each other by sharing expert resources and experimental facilities. This paper describes the programs in 1999/2000, to provide an overview of the scope of the programs and the issues that these programs address.

1.0 Introduction

Fuel development activities in Canada have been, for a number of years, driven by two requirements. The first requirement is to address issues that are related to fuel operation and performance. To meet this need, the Canadian utilities - Hydro-Québec, New Brunswick Power, Ontario Power Generation Inc .- and Atomic Energy of Canada Limited (AECL), jointly or in part, support work programs under the CANDU Owners Group (COG). The focus of these COG programs is to maintain and improve the reliability, economics, and safety of the 28- and 37-element natural-uranium CANDU fuel bundles in operating stations. The second requirement is to improve the CANDU fuel products. The focus of these programs is to develop advanced fuel bundles and fuel cycles that will reduce capital and fuelling costs, increase the operating and safety margins, improve natural-uranium utilization, and provide synergy with other reactor systems to improve resource utilization and spent fuel management (Reference 1). These programs are supported by AECL in its Advanced Fuel and Fuel Cycles Technology Program.

The COG and the AECL fuel development programs have complemented each other for many years. The programs have shared technical expertise as well as the experimental facilities. The results from one program have also been valuable for the performance and direction of the other, and vice versa.

Since the review of the Canadian fuel development programs at the CANDU Fuel Conference in 1997 (Reference 2) *(See CNS Bulletin, Vol. 18, No. 3)*, the AECL Advanced Fuel and Fuel Cycles Technology Program has met a number of important milestones. One of them is the demonstration irradiation of 24 CANFLEX bundles at the Point Lepreau Generating Station (PLGS). This is a prerequisite to the full-core implementation of the CANFLEX bundles in a power reactor.

During the same period, the COG Fuel Technology Program has also been making important achievements. For example, the irradiation of 37-element bundles with different design parameters was completed at the PLGS. The post-irradiation examination (PIE) of the irradiated fuel elements has since been conducted in the hot-cells at Chalk River Laboratories (CRL) and has provided valuable information on the behaviour of fuel elements that have different UO_2 densities and UO_2-sheath clearances.

Since 1997, the size of the COG Fuel Technology Program has been significantly reduced for several reasons. Many of the existing programs that address issues of common interest to the utilities have been successfully completed. The fuel has also been performing very well in reactors. Additional issues of common interest are therefore fewer and are considered to be of lower priority. Finally, the re-structuring of COG and

1 Atomic Energy of Canada Ltd., Sheridan Park
2 Atomic Energy of Canada Ltd., Chalk River Laboratories
3 New Brunswick Power, Point Lepreau
4 Ontario Power Generation Inc.
5 Hydro-Québec, Gentilly 2

Table 1: Fuel Bundle Defects in Canadian CANDU Stations in 1997 and 1998

Station / Year	Estimated No. of Defects	Confirmed Defects					No. of Discharged Bundles
		Fretting	Manu.	SCC	Unassigned	Total	
Bruce A							
1997	0	0	–	–	–	0	7472
1998	1	1	–	–	–	1	1298
Bruce B							
1997	1	1	–	–	–	1	20550
1998	2	2	–	–	–	2	17602
Darlington							
1997	2	–	–	–	–	0	15508
1998	5	–	–	–	–	0	21349
Gentilly							
1997	1	–	1	–	–	1	4324
1998	0	–	–	–	–	0	3900
Pickering A							
1997	2	–	–	–	–	0	8054
1998	0	–	–	–	–	0	0
Pickering B							
1997	1	–	–	–	–	0	9424
1998	3	–	–	–	–	0	11740
Point Lepreau							
1997	3	1	–	–	2	3	3488
1998	0	–	–	–	0	0	3828
Total for All Stations	21	5	1	0	2	8	128537
Cumulative 2-yr. Bundle Defect Rate based on Estimated No. of Defects				0.016%			
Cumulative 2-yr. Bundle Defect Rate based on Confirmed No. of Defects				0.006%			

the attendant budget changes have effected a funding reduction in the Fuel Technology Program. It is anticipated that the effort in the COG Fuel Technology Program would be augmented in the future by direct utility support, for fuel-related issues that are specific to each utility.

In this paper, the fuel performance data for the Canadian CANDU stations is first presented. As noted earlier, the fuel performance has been very good. The Canadian fuel development programs in 1999/2000 are then described in the paper, to provide an overview of the scope of the programs and the issues that these programs address.

2.0 Fuel Performance in Canadian CANDU Stations

One of the typical measures of fuel performance is the fuel-bundle defect rate, expressed as the percentage of the bundles in which sheath failure has occurred during irradiation. The means of fuel defect detection, and the convention of reporting the number of fuel defects differ among the Canadian CANDU stations. The Bruce A, Bruce B, Point Lepreau and Gentilly-2 nuclear generating stations (NGSs) have the gaseous fission-product monitoring system (GFP) to monitor the activity level in the heat-transport coolant, and the delayed-neutron scan system to locate the channel that contains the failed fuel. The Darlington NGS has the GFP system only. The Pickering NGS A and NGS B monitor the activity in the heat transport coolant using grab-samples.

In addition to the coolant activity level, the other indicators of fuel defects include coolant activity changes upon fuelling, gamma signals and alarms when the fuel is discharged, wet sipping performed on the suspect discharged fuel, and inspection of the suspect bundle in the fuel bay. Some stations report a fuel defect when there is strong collaborative evidence from the defect indicators. Some stations report the number of estimated fuel defects, and report confirmed defects only when the defects are visually confirmed during inspections in the fuel bay. Therefore, depending on the monitoring system available at the stations and the reporting convention, the number of estimated fuel defects may be an overestimate, whereas the number of confirmed fuel defects may be an underestimate of the actual number of fuel failures.

Table 1 summarizes the number of estimated and confirmed fuel-bundle defects reported in the Canadian CANDU stations for the years 1997 and 1998. Note that the number of estimated defects include the confirmed defects. For the confirmed fuel defects, the causes are also indicated in the table. The causes of the fuel defects are classified into 4 types:

i) Debris fretting, caused by debris in the heat transport system, that lodges within the fuel bundle and frets through the sheath;
ii) Manufacturing-related defects;

iii) Stress corrosion-cracking defects (SCCs), normally associated with power ramps;
iv) Unassigned, i.e., defects for which the root causes were not identified.

Of the stations listed in Table 1, the Gentilly-2 NGS and the PLGS each has a single reactor unit. The Bruce A and B, Darlington, and the Pickering A and B NGSs all have 4 nuclear reactors per station. The Pickering A and Pickering B stations use the 28-element fuel bundles, and the other stations use the 37-element fuel bundles. Some reactor units were shut down, or outages have occurred in others at some time during the two-year period. The operating history has been reflected in the number of bundles discharged from the stations.

The cumulative fuel defect rates over the two-year period for all Canadian CANDU stations, expressed as the percentage of the number of bundle defects to the total number of bundles discharged, were very low. The fuel defect rate is 0.006% for confirmed defects, and 0.016% for all estimated defects. The actual fuel defect rate is therefore between 0.006% and 0.016%. This operating record demonstrates excellent performance for CANDU fuel. Because most failed bundles involve only one fuel element, the element defect rate over the two-year period for all discharged bundles in Canada is on the order of 0.0002% to 0.0005%.

Five out of the eight confirmed fuel defects were attributed to debris fretting. This category of fuel defect should ideally have been excluded in the calculation of the defect rate because debris fretting is beyond the control of fuel design and fuel manufacturing, and is therefore not related to fuel performance. Two out of the eight confirmed fuel defects were attributed to unassigned causes, and one was a manufacturing related defect. Between 1997 and 1998, fuel performance has not been a concern and has not caused any loss of power generation in any of the Canadian CANDU stations.

3.0 COG Fuel Technology Programs

Since the last review of the COG Fuel Technology Program a number of activities funded under this program have been completed. Four activities that deal with issues of common interest to all COG partners continue into 1999/2000. They include a review of fuel specifications, PIE of fuel, compilation of an irradiated fuel database, and validation of the ELESTRES -IST code.

3.1 Fuel Specifications Review

The review of the fuel technical specifications and the documentation of the rationale for the specification limits continue into 1999/2000. The review identifies any needs for updating the specifications, in order to capture new information from research and development, manufacturing, and operating experience. By documenting the rationale, the reasoning behind the specifications can also be understood by the users, and this understanding provides additional quality assurance in the fuel procurement process. The documentation of the rationale is also necessary for the training of newcomers to the nuclear fuel industry.

As of the writing of this paper, the reviews of all the specifications for fuel materials and parts have been completed and documented. A result of this review, which deals with the hydrogen gas limit in fuel elements (Reference 3), will be described in this conference.

3.2 Post-irradiation Examination of Fuel

The PIE of fuel that is of common interest to the Canadian CANDU stations is being continued in the 1999/2000 program. In 1998, two fuel bundles from the Gentilly-2 NGS that were in a channel with diametrally crept pressure tube were examined. The purpose of this examination was to determine whether creep, which is a part of reactor aging, has any visible effects on fuel behaviour and performance (Reference 4). In 1999, it is planned to examine fuel bundles that resided near the liquid zone controllers and hence had been subjected to many power changes, to see whether power changes affect fuel performance.

The irradiation and PIE of six "special" bundles were also of generic interest. These were bundles specially fabricated to (i) high and low UO2 densities, (ii) large and small diametral clearances, and (iii) with and without a CANLUB coating. These "special" bundles were all irradiated at the PLGS. Bundles with high and low densities and with large and small clearances were examined at the hot-cells at CRL in 1998. The objective of these PIE was to provide the designers with in-reactor data, to confirm the technical specifications of density and clearance. (The results of the PIE are presented in Reference 5). In 1999, irradiated bundles with and without CANLUB coating will be examined to investigate any effect of the CANLUB coating on the fuel chemistry and fuel temperature.

3.3 Irradiated Fuel Database

An electronic database of fuel behaviour parameters including fission-gas release, sheath strain, power-burnup history, etc. has been compiled, using the PIE results of CANDU fuel elements irradiated in the power reactors and test reactors. This database will be used extensively for the validation of the fuel behaviour code ELESTRES-IST. In 1999, the database will be updated to include additional data that have since been collected. At present, the database consists of about 337 cases, about one third from power reactors, and the rest from irradiation in test loops or reactors.

3.4 ELESTRES-IST Code Validation

The ELESTRES-IST code is supported by the COG partners as the industry standard toolset (IST) for modelling fuel-element behaviour during reactor operation. The code, based on the finite-element technique, combines the features in the ELESIM (Reference 6) and the ELESTRES (Reference 7) codes. The IST version has been subjected to vigorous tests to ensure the stability of the numeric schemes, and to examine any discontinuities in the code predictions.

Verification and validation of the ELESTRES-IST code will start in 1999. The validation will be performed on a phenomenological basis, in which key phenomena that the code models will be identified, appropriate irradiation data for validation of the phenomena will be compiled, and the code's predictions will be compared with the compiled analytical data. Upon completion of the phenomenological validation, the code will be validated by comparing the code's predictions with irradiation data on an integral basis.

4.0 AECL's Advanced Fuel and Fuel Cycles Technology Program

The Advanced Fuel and Fuel Cycles Technology Program at AECL has three categories of activities. The first category deals with the development of new fuel bundle designs that can be used for the natural-uranium fuel as well as other advanced fuel and fuel cycles. For example, the 43-element CANFLEX bundle has been developed as a successor to the 28-element and 37-element bundle designs. Incorporating the critical heat flux (CHF) enhancement buttons, the CANFLEX bundle offers higher critical channel power (CCP) performance compared with that of the 28-element and the 37-element fuel bundles. Hence the use of the CANFLEX bundles in reactors will increase the operating margins, or permit power uprating (Reference 8). At the same time, by subdividing the bundle into a larger number of elements, and by using two different element sizes, the CANFLEX bundle has a 20% lower peak linear element rating compared with that of the 37-element bundle for the same bundle power output. These features make the CANFLEX bundle an ideal carrier for the advanced fuel cycles that demand operation at higher fuel burnup.

The second category of programs deals primarily with the fuel matrix, and includes activities in plutonium mixed-oxide fuel, DUPIC fuel, thorium fuel, and other alternate fuel and fuel cycles. Using the CANFLEX bundle as the carrier for the advanced fuel and fuel cycles, these programs focus on the fuel element performance, fabrication optimization, thermalhydraulic performance, as well as the core physics, fuel management, and economic aspects of these advanced fuel cycles.

The third category consists of programs in fuel-supporting technologies. These programs deal with the maintenance and improvement of fuel design technologies, such as the update of fuel specifications and the validation of fuel-design computer codes. These programs also support the development of improved design features, such as the optimized fuel-element design for high burnup operation, the enhancement in CHF performance, and the improved method of appendage attachment. Upon completion of the development, these features will be deployed in the advanced fuel bundle design.

4.1 CANFLEX Fuel Bundles

The CANFLEX-NU (natural uranium) bundle program has reached an important milestone since the last review at the 1997 conference. On September 3, 1998, 8 CANFLEX bundles were loaded into the PLGS to begin the 24-bundle demonstration irradiation program. A report of the demonstration irradiation program and its status is given in Reference 9 *(See also CNS Bulletin, Vol. 20, No. 2)* To date, 24 bundles had been loaded into two channels under normal fuelling, and eight bundles have since been discharged, four from each channel. The immediate plan is to select one of these eight discharged bundles for shipment to the hot-cells at CRL for a detailed destructive examination to confirm the fuel's performance.

The eight discharged bundles successfully completed their normal residence times in the reactor. During the irradiation, the fuel performance was monitored, as usual, with the failed fuel monitoring systems, and there was no indication of any fuel failure. The preliminary inspection of these bundles in the fuel bay shows no abnormal behaviour. Some markings were reported on the end plates during the bundle inspection at the fuel bay. However, it has since been confirmed that these markings were made during the manufacture of the end plates and were not caused by interactions with the fuel handling systems.

During the past year, the focus of the CANFLEX-NU program is to complete all the necessary design work, to allow for full-core implementation of the CANFLEX bundles. The CHF measurements in Freon have shown that the CANFLEX bundle will provide a significant increase in the CCP because of the use of the CHF enhancement buttons. This has since been confirmed by water CHF tests performed at the STERN Laboratories during 1999. The water CHF tests were done in a full-size channel rig with 12 CANFLEX-bundle simulators that were heated by internal heaters. The CHF locations were measured by sliding thermocouples. The CHF test program is now complete and is described in a paper (Reference 10) presented at this conference.

Another achievement in the past year is the completion of the second cross-flow test on the CANFLEX fuel bundle, performed at the Korean Atomic Energy Research Institute (KAERI)[6] . The cross-flow test simulates the bundle when it resides in the liner tube region of the end-fitting during on-power refuelling. The original cross-flow test, performed in 1996, confirmed that the CANFLEX fuel bundle can withstand cross-flow conditions in excess of 4 h. This time limit exceeds the design requirement that specifies that bundles would reside in the cross-flow region for up to 4 min during refuelling. However, from an operational standpoint, it is desirable to know the time limit that the bundle can remain in the cross-flow region without incurring any damage. This time limit will then define the allowable recovery time if an abnormal fuelling event occurs in which bundles are stuck under the cross-flow conditions. The follow-up cross-flow test was successfully performed at KAERI in early 1999 to quantify this time limit.

In addition to the above tests, further design analyses were completed in the past year to provide further confirmation and support to the in-reactor and out-reactor fuel qualification tests. These analyses include, for example, mechanical analysis of the stresses on the bundles during fuelling, end flux peaking, etc. These analyses are discussed in References 11 and 12.

6 The CANFLEX bundle has been developed jointly by AECL and KAERI since 1991; before that by AECL since 1986

By April 2000, the supporting design work for the full-core implementation of the CANFLEX-NU bundles will be complete. An exception would be the PIE of one of the CANFLEX bundles that will be discharged from the PLGS in the year 2000. The remaining work required for full-core implementation, which is not a part of the supporting design activities, includes the safety analyses that are required to obtain license approval, the activities at the station associated with implementing a new fuel type, and the procurement of CANFLEX bundles. Although AECL is expected to provide significant effort to support these remaining tasks, the lead will be provided by the staff of the PLGS.

With the CANFLEX-NU design work mostly completed, AECL's development effort will now focus on the CANFLEX-SEU (slightly enriched uranium) fuel. One of the advantages of enrichments of up to 1.2% in a CANDU reactor is to allow flattening of the core flux distribution, which leads to a higher core power for the same size core. This is a major benefit because it can reduce the unit capital cost of new reactors. By using enriched fuel, it also has the advantage of reducing the volume of spent fuel, and hence reducing the back-end costs associated with spent fuel storage and disposal (Reference 13). Recovered uranium (RU) from the reprocessing of spent LWR fuel is a variation of the SEU cycle. RU, which has an enrichment of about 0.9%, is expected to be a low-cost alternative to the conventional SEU. The CANFLEX-RU work is a joint program by AECL, British Nuclear Fuels Limited (BNFL) and KAERI (Reference 14).

In 1999/2000, the AECL program on CANFLEX SEU/RU fuel is to begin the design verifications that are necessary to qualify the CANFLEX SEU/RU fuel bundle. The design verification will include all the tests and analyses that would support the demonstration irradiation of CANFLEX SEU/RU bundles in a power reactor. Reactor physics simulations are also being performed to establish a reference CANFLEX SEU/RU core design. In the areas of safety analysis, a review of the implications of the use of CANFLEX RU/SEU fuel in the consequences of all design-basis accidents will be performed, to define the work scope for more detailed assessment.

The CANFLEX bundle has been qualified for the channel flow rates in present CANDU reactors. However, for advanced core designs, it would be desirable to define the high flow limit to which the CANFLEX bundle can operate. A higher channel flow will allow up-rating of the channel power, which in turn can reduce the capital cost of a reactor. In 1999/2000, an investigative program is planned to measure the fuel vibration levels and the fuel and pressure tube fretting-wear rates of the CANFLEX bundles under high flow conditions. The test will be performed in the flow visualization rig at AECL's laboratory at Sheridan Park. The test rig consists of up to four CANFLEX bundles in an acrylic pressure tube section simulating the fuel channel inlet. The bundles will be subjected to channel flow rates in increasing increments, and the vibration levels of the bundle will be measured.

4.2 Advanced Fuel and Fuel Cycles

For years, AECL has maintained a number of advanced fuel and fuel cycles programs. These programs aim to establish the technical feasibility, to improve the fabrication processes, and to provide process data for economic evaluation of the various advanced fuel and fuel cycles. These research and development programs (Reference 2) — including low void reactivity fuel, DUPIC fuel cycle, thoria fuel, Pu mixed-oxide fuel, inert-matrix fuel—are continuing into 1999/2000. Some of these programs are discussed below:

4.2.1 DUPIC Fuel

The DUPIC fuel cycle (Direct-Use of spent PWR fuel in CANDU) involves converting the pressurized-water reactor (PWR) spent fuel into the CANDU fuel using a dry process called OREOX. By subjecting the PWR spent fuel to repeated oxidation and reduction processes (OREOX), selected fission products that are highly neutron-parasitic can be removed. The resulting powder, when fabricated into CANDU fuel, can be used directly in a CANDU reactor. The OREOX process provides a higher degree of proliferation resistance than conventional reprocessing. The DUPIC program is jointly sponsored by AECL, KAERI, and the US Department of State. At AECL, three DUPIC elements were fabricated at AECL's Whiteshell Laboratories (Reference 15). These elements are now being irradiated in the NRU reactor at CRL. The activities in fabrication and irradiation are aimed at confirming the technical feasibility of the cycle, optimizing the process, and obtaining data for economic assessment.

4.2.2 Thorium Fuel Cycles

For the thorium fuel cycles, AECL maintains an ongoing program in thoria fuel fabrication, test irradiation, and fuel management studies of thoria-fuelled CANDU cores (References 16 and 17). In 1999/2000, further fabrication development will be carried out, which would lead to a test irradiation in order to provide performance feedback to qualify the improved fabrication processes.

4.2.3 Pu Mixed-oxide Fuel

The higher initial enrichment and discharge burnup of light-water reactor (LWR) fuel, compared with the CANDU fuel, result in a higher concentration of plutonium in the spent fuel. The plutonium from the reprocessing of LWR spent fuel can be fabricated into mixed-oxide fuel and used in the CANDU reactor. Because of the higher neutron economy, twice as much energy can be derived from the plutonium in a CANDU reactor than in a LWR. AECL maintains a program of mixed-oxide fuel fabrication and irradiation, to acquire additional data in performance behaviour and fabrication processes. Some of the results were presented in Reference 18.

A variation of the application of Pu mixed-oxide fuel is the dispositioning of weapons-grade plutonium. This involves the fabrication of mixed-oxide fuel, using weapons-grade plutonium, and utilizing this fuel in a CANDU reactor. Canada, through AECL, is participating in the weapons-grade Pu disposition program with the United States and the Russian Federation (Reference 19).

4.2.4 Inert-matrix Fuel

AECL has an ongoing development program in inert-matrix fuel. Inert-matrix fuel is fuel in which a fissile component, plus optional actinide-wastes, are incorporated in an inert-matrix, i.e., a matrix which does not produce Pu or higher actinides. Actinide wastes, especially 241Am, 237Np and 244Cm, which are concentrated during reprocessing and are the most carcinogenic, can be annihilated. The destruction of weapons-grade or reactor-grade plutonium is another application.

Several candidates for use as the inert-matrix are studied worldwide, including zirconia, spinel, and other materials. Over the last four years, AECL has examined silicon carbide (SiC) as a potential inert-matrix. SiC has several material properties which make it an excellent candidate—extremely high thermal conductivity (leading to fuel centerline temperatures as low as 100°C above coolant temperature), resistance to oxidation and low neutron absorption.

The physics of annihilation of Pu and the actinides in CANDU reactors with this fuel have been studied and show that the versatility of the CANDU reactor can allow full-core loading. Consequently, disposition rates of the actinides are high (Reference 20). In addition, studies in fabrication, compatibility with coolant water, compatibility with Zr-based cladding under accident conditions, waste disposal and accelerator-simulations of in-reactor damage have been conducted (Reference 21). The results confirm that SiC is an excellent candidate for inert-matrix fuel.

4.3 Fuel-supporting Technologies

AECL maintains a program of technology development to support the advanced bundle design and the deployment of advanced fuel cycles. One technology is the development of high burnup fuel, which has a target burnup of about three times that of the present natural-uranium fuel. Currently, fuel elements designed for high burnup operation are being irradiated in the NRU reactor at CRL. A program has also been initiated to extend the stress corrosion cracking (SCC) thresholds to higher burnup, through analytical modelling, irradiation, and power ramp tests.

Another development activity is the improved technique of attaching appendages to the Zircaloy fuel sheath. Currently, the attachment of bearing pads and spacers in the CANDU 28- and 37-element bundles, as well as the CHF buttons in the CANFLEX bundles, are being done by beryllium brazing. Although this attachment technique has proven to be very reliable, as confirmed by the very low number of fuel defects in CANDU reactors, it has been known that the heat-affected zone in the braze region is the part of the sheath that is most susceptible to SCC. Although at present, SCC does not pose a fuel performance limitation, there is still an advantage to increase the margin to SCC, particularly for fuel that operates at high burnup. The improved attachment techniques aim to reduce or eliminate the heat-affected zone.

Another activity in fuel-supporting technologies is to maintain and improve AECL's fuel design capability. To this aim, AECL funds the revisions to the fuel specifications. At present, all fuel specifications for fuel parts and materials have been revised, and the specifications have been issued to all Canadian CANDU utilities, the Canadian fuel manufacturers and the uranium supplier for their comments. It is expected that these revised specifications will be formally issued by the end of 1999.

Another activity is to maintain and improve the fuel design codes (References 22 and 23). In addition to the ELESTRES-IST fuel-element code, AECL maintains a suite of fuel design codes that range from dedicated finite-element codes for assessing stress on end plates and end caps, to specialized codes for assessing SCC susceptibility. These codes are being subjected to a vigorous program of verification and validation, to bring them to the current QA standards recommended by the

Clarification of CANFLEX "deformations"

Ed. Note: Patrick Reid, an author of the paper cited below, sent in this note providing a further explanation of a particular point in that paper.

In the paper entitled "CANFLEX Demonstration Irradiation at Point Lepreau", published in the CNS Bulletin Volume 20, No. 2, there was a discussion of some endplate markings (called "minor endplate deformation" in the paper) which had been observed on the CANFLEX bundles which had been discharged from the reactor. At that time, the cause of the markings had not been identified, although the paper included a brief discussion of some of the possible causes.

Thanks to the co-operation of staff from NB Power, AECL and Zircatec Precision Industries in evaluating these observations, it has been possible to identify the cause of these markings. They are a normal by-product of the manufacturing process used for the production of the end plates for the 26 CANFLEX bundle which were made for the Demonstration Irradiation. CANFLEX end plates for this order were manufactured by a qualified supplier using Electrical Discharge Machining (EDM) as is routine for small orders. The observed markings were witness marks remaining after the manual deburring operation which is part of this process. Although this leaves markings on the end plates which are not present in end plates manufactured by the more usual stamping process, product specifications are in no way compromised.

In the event that CANFLEX fuel bundles were to be made on a large scale, such as for an entire reactor fuel order, it is most likely that the usual stamping process would be used for the end plates.

Canadian Standards Association.

The fuel design codes are useful in assessing whether operating power transients may incur a risk of fuel defects or whether certain fuel manufacture deviations may have an adverse effect on fuel performance. The codes are also useful to assess the sensitivity of fuel performance to design parameters. The codes can also be a means for design qualification, replacing some of the qualification testing that needs to be done if the codes are not available. In the latter case, analyses with validated codes may reduce the reliance on qualification testing, and in so doing, may provide a means to reduce the cost, and shorten the time period from product conception to commercialization.

To complement the development of fuel performance codes for high burnup application, an investigative program of obtaining physical properties of fuels, such as diffusion rates, thermal properties, and chemistry is also being conducted. A new technique to measure fission-product diffusion coefficient in UO2 fuel using the accelerator and secondary-ion mass spectrometry was recently developed (Reference 24).

5.0 Concluding Remarks

The Canadian CANDU fuel development programs in 1999/2000 have been described in this paper. The programs consist of the COG-sponsored Fuel Technology Program and the AECL's Advanced Fuel and Fuel Cycles Technology Program. The programs cover operational issues related to the present 28- and 37-element fuel, and new advanced products such as the 43-element CANFLEX bundles and advanced fuel cycles. These programs, directly and indirectly, contribute to the remarkably good fuel performance that has been experienced by the Canadian CANDU stations. These programs also support advanced fuel bundles and fuel cycles that would lead to the benefits of capital and fuelling costs reduction, operating and safety margins increase, and improvement in natural-uranium utilization and spent fuel management.

Acknowledgment

The authors would like to acknowledge P.G. Boczar (AECL), R. Lee (OPG), R.W. Sancton (NBP), and R.A. Verrall (AECL) for their valuable input and comments during the preparation of this paper.

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CANDU Fuel: Design/Manufacturing Interaction

by N. A. Graham[1]

Ed. Note: The following paper was presented in a special "history" session at the 6th International Conference on CANDU Fuel held in Niagara Falls, Ontario, September 1999.

Abstract

The design of CANDU fuel has been the product of intense cooperation among fuel designers and fuel manufacturers. The developments of some of the novel processes in fuel manufacture are outlined. These include the brazed-split-spacer design, the resistance welded endcap and CANLUB coatings.

Introduction

The evolution of many features of CANDU fuels has been the product of intense interaction and co-operation between the fuel designers and fuel manufacturers. The fuel engineers established the general design requirements for the fuel and fuel manufacturers developed the processes and equipment to manufacture the fuel, at a production scale.

In the early stages of the design of a new reactor, the fuel design requirements would be established. The general procedure was then for the fuel design engineers at AECL to request the fuel manufacturers to provide prototype fuel elements or bundles for irradiation testing in the NRX or NRU reactor test loops at Chalk River Labs (CRL). This request took place in several stages; it often started with contracts for process development, where new features were contemplated, and then continued with contracts for small quantities of fuel elements and fuel bundles for the irradiation testing program. The manufacturing processes have evolved from these early "first-off" model shop scale methods to well established controlled production processes today.

Throughout the development of fuel designs and manufacturing production methods, the emphasis has always been on product quality, manufacturability and fitness for purpose; i.e. defect free fuel for the burnup life of the fuel under normal operating conditions, including fuel handling.

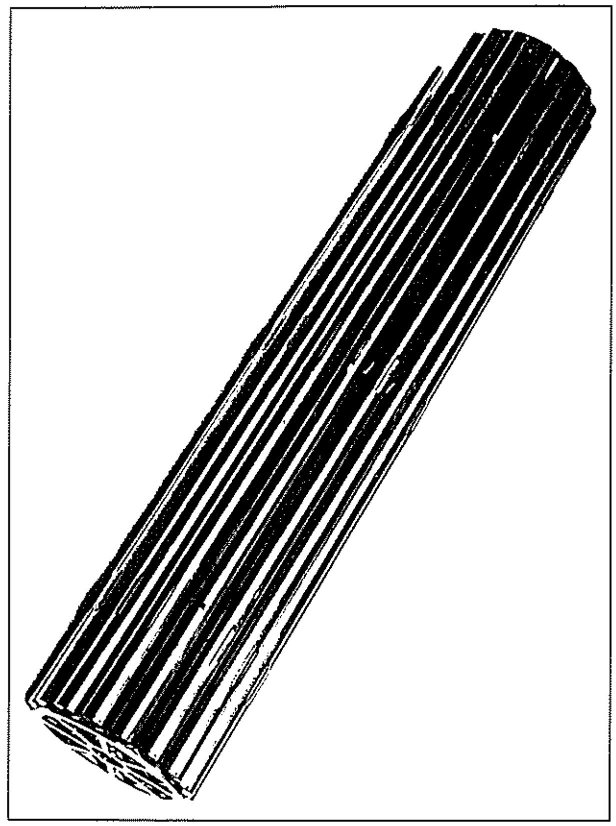

Figure 1: Pickering 28 Element Fuel Bundle; Brazed-Split-Spacer Design.

Brazed Split Spacer Design

In my opinion, the brazed-split-spacer concept is one of the more significant developments in the evolution of the CANDU fuel design. It was first incorporated in the 19-element Douglas Point fuel bundle[1] and has become the mainstay in all later CANDU fuel designs. (Figure 1,2) The evolution to this design concept did not come easily and went through many trials and tribulations, mainly during the late fifties and early sixties.

The earlier fuel design for NPD, and initially for Douglas Point, employing the welded-wire-wrap con-

1 Norman Graham is a consultant living in Cobourg, Ontario. Before his nominal retirement he was with Zircatec Precision Industries and its predecessor, Westinghouse Canada.

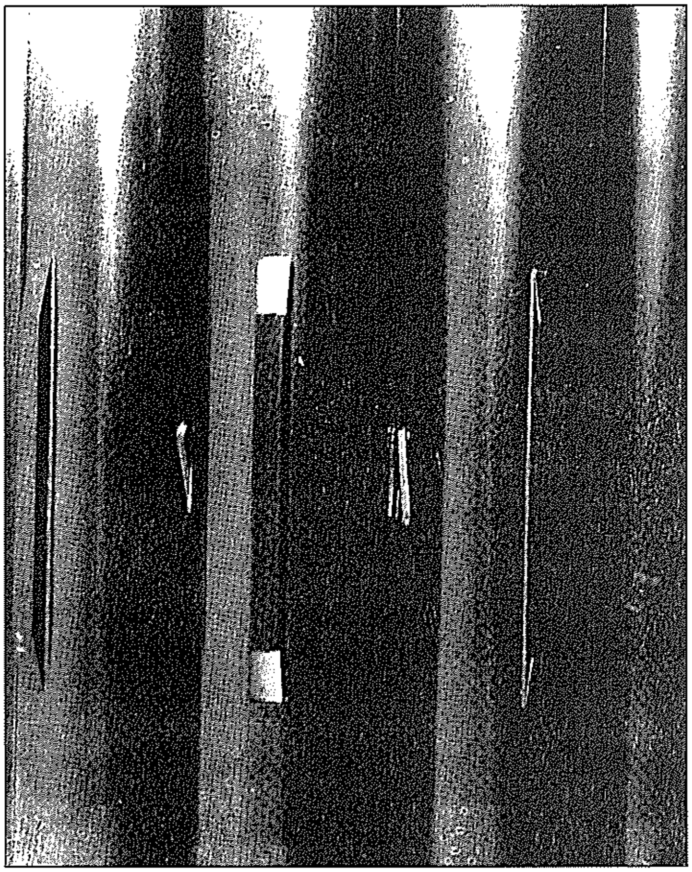

Figure 2: Close-up of Brazed-Split-Spacers and Bearing Pads.

cept for inter-element spacers and bearing pads, had performed well. However, out-reactor testing at higher flow rates that would be required in later reactor designs, had shown evidence of fretting damage of the thin wall fuel sheath by the contacting wire spacer. The concern for this fretting damage prompted a search for other design approaches that would avoid this problem. This split-spacer approach was identified fairly early-on; however, finding a good method of attachment of the split-spacer to the sheath was more elusive. The methods that were considered included various forms of resistance welding and resistance brazing; but they all had serious drawbacks[1,2]. Resistance welding had concerns for possible crevice corrosion in the gap under the pad and for possible damage to the fuel sheath by the welding process. Resistance brazing showed some early promise but the process became nearly impossible, due to current shunting when trying to assemble more than two or three elements at a time.

During the 50's, researchers at Armour Research Labs had been looking for possible brazing alloys for zirconium[3,4]. From all the alloy systems that were investigated, which included aluminum, copper, iron, nickel and others, they concluded that the Zr-5 w/o Be eutectic (m.p. 960EC) could be recommended (Figure 3,4); it had good joint wetting properties and high mechanical strength and exhibited reasonable corrosion resistance in high temperature water.

In 1958 we, in Canada, began a program to develop methods to braze spacer appendages on fuel sheaths[5]. Initially, the thrust was to obtain quantities of the brazing alloy and to examine ways of applying these in the spacer/sheath joint. Small ingots of the Zr- 5 w/o Be alloy were obtained from reactive metal suppliers: Mallory, Heraeus, Nuclear Metals Inc. (NMI), and Nuclear Material and Equipment Co. (Numec). This alloy is very hard and attempts to form it into useful shapes for pre-placement were not successful, although NMI did produce a small quantity in wire form. Other developments included pre-placing the alloy in the joint as a powder paste, like Nicrobraz for stainless steels. Although samples of powder were made, by pre-hydriding, crushing/grinding and de-hydriding, its use as a brazing alloy was not successful; the powder was difficult and messy to preplace on the parts and the brazed joint was very poor due to much porosity.

A break-through in the problem of preplacing the brazing alloy came with the discovery that beryllium metal would react directly with Zircaloy to form the Zr-Be brazing alloy in-situ. This led to preplacing the beryllium as a vapour deposited coating on the spacer component. The development of methods for vapour coating beryllium was further assisted by being able to use a small bell-jar coating unit in a beryllium handling facility that was already established at Westinghouse labs in Hamilton. This facility provided beryllium coated Zircaloy sheet samples which were then used to form spacer and bearing pad appendages for the development of brazing methods[6].

A further breakthrough in spacer brazing was the development of vacuum induction brazing for heating the joint to the eutectic melting temperature[6]. This led to the development of a unit which was able to braze many sheaths at one time. (Figure 5)

Resistance Welded Endcaps

A very early example of design/manufacturing interaction is the resistance welded endcap for sealing the ends of fuel elements[7]. The very early CANDU fuel for the NPD reactor had

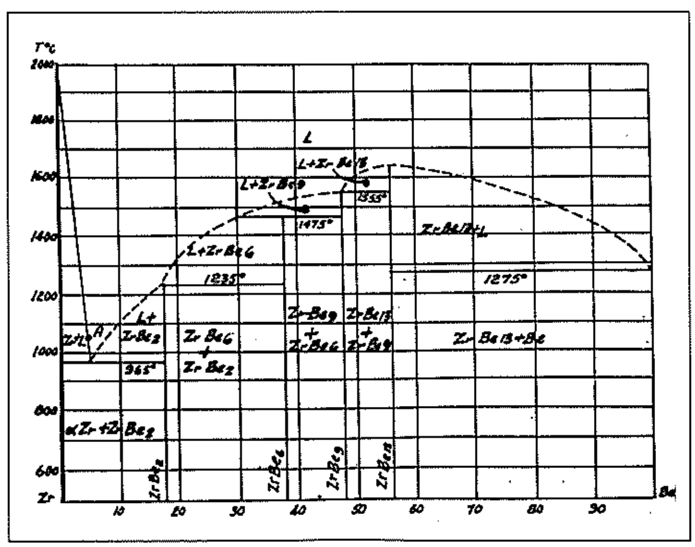

Figure 3: Phase Diagram Zr-Be System

Figure 4: Metallographic Section of Brazed Fillet Joint

fusion welded endcaps, but fuel manufacturers recognized that the fusion welding process would become very onerous in practice, recognizing the large numbers of fuel element end closures required in the short fuel bundle in CANDU reactors. In looking for alternative end closure processes, the fuel manufacturers were attracted to resistance welding methods; this is an inherently fast process, well suited to repetitive production requirements, and the resistance welding technology and control equipment had been developed to a high degree for the aircraft industry. As early as 1958 the fuel manufacturers had assembled developmental equipment and were providing resistance welded endcaps on experimental fuel elements for irradiation testing in test loops at CRL.

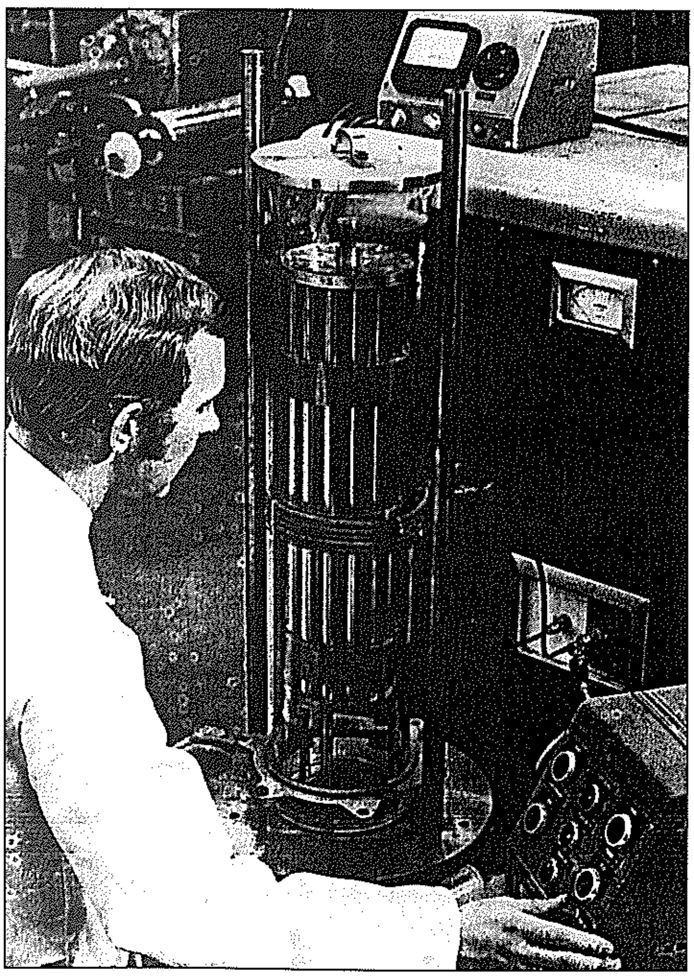

Figure 5: Early multiple-tube vacuum induction brazing

The endcap weld is essentially a ring projection weld between the outer rim of the endcap and the end of the fuel sheath; it would be equivalent to a line resistance weld about one and a half inches long. All CANDU Fuel manufacturers employ similar endcap welding processes but there are detail differences; the internal endcap geometry, and the shapes of the flaying surfaces to be welded, are proprietary to the fuel manufacturers. The external shape of the endcap is specified by the fuel designers and is required to accommodate the fuel handling tooling, i.e. side-stops and latches.

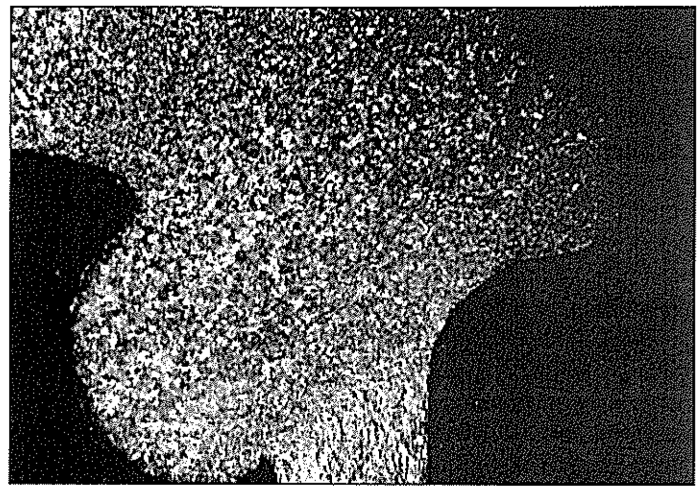

Figure 6: Section through end cap resistance weld

A section through the endcap weld from one manufacturer is shown in Figure 6. To make the weld, the endcap is held on the end of one electrode and the fuel sheath is held in essentially a ring collet which is the other electrode. An axial force is applied at the same time as the resistance welding current is discharged, heating the interface and forming the weld. The weld is really a hot forging process and the excess material from the weld upset, termed the weld flash, pushes out at both sides of the weld. In a subsequent operation, the external weld flash is machined-off to maintain the specified diameter of the fuel element.

Today's endcap welding process is essentially the same as that developed more than thirty years ago, although the quantity of fuel manufactured each year has increased many fold. The manufacturers have accommodated these increased quantities while maintaining high quality levels, through improved tooling, programmable process controllers and automation for material and product handling.

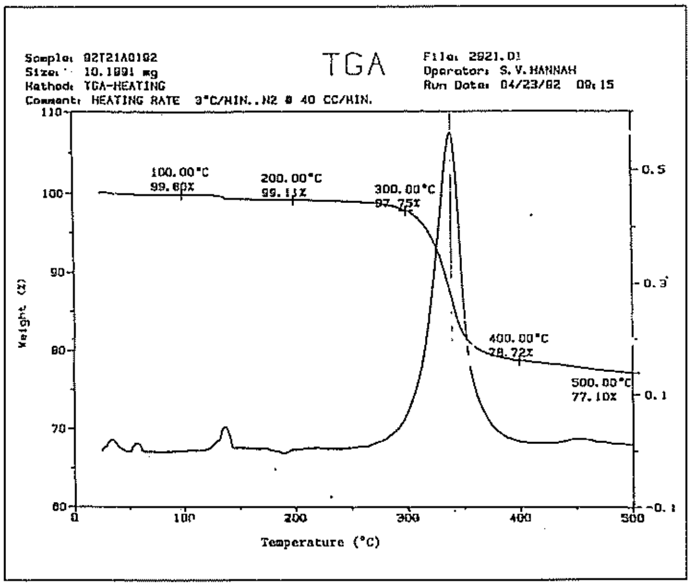

Figure 7: Thermograph Alcadag 154

CANLUB Coatings

Another significant development in the evolution of CANDU fuel designs has been CANLUB coatings. This development was driven by the urgency to provide a fix to prevent fuel failures following power changes during on-power refueling. Although this problem had occurred at Douglas Point it became more serious during the early operations of the Pickering reactors during the early seventies. Comparison of the crack morphology in fuel sheaths from power ramped fuel bundles, with cracking produced in the laboratory in iodine mixtures, had suggested that the defects were due to a stress-corrosion-cracking (SCC) mechanism. It was believed that iodine, or other SCC corrodents, originate in the fission products which are released from the fuel into the fuel-sheath gap.

An industry-wide working party was set-up to investigate the power-ramp defect problem and to find a solution. Most of the remedies that were suggested were aimed at reducing the pellet/sheath friction during fuel expansion; these included graphite coatings on the sheath interior or on the pellet surface, low density pellets and pressurized elements. From tests of these, graphite coatings proved to be most consistently effective. The first graphite coatings employed were on fuel elements which were tested in NRX reactor loops[8]. These coatings employed DAG 154, a graphite filled lacquer which was available at CRL and is supplied commercially by Acheson Colloids Ltd., primarily to the electrical industry for use as conductive coatings. The CANLUB graphite coatings were so successful in preventing power ramp defects that fuel manufacturers were requested to set up production facilities as soon as possible.

The initial CANLUB coating procedure employed at CRL involved smear-coating the DAG - 154 lacquer on the inside surface of the fuel sheath, followed by air drying to evaporate the solvents and baking in a vacuum oven at about 350EC to decompose and drive-off the organic binder (Figure 7). The manufacturers proceeded to set-up essentially similar processes for applying CANLUB coatings on a production basis. Very quickly the manufacturers began producing CANLUB coatings in limited quantities, employing bench-scale fill-and-drain or flood coating-and-drain techniques followed by vacuum baking in laboratory vacuum furnaces.

In order to employ CANLUB coatings in as many Pickering fuel bundles as possible, from these limited early facilities, the fuel designers initially specified CANLUB in only the outer elements. This allowed CANLUB fuel bundles to be employed quickly in the more vulnerable high power channels. This requirement for CANLUB in the outer elements only has persisted in Pickering fuel until fairly recently when the inconsistency was recognized; Pickering fuel is now supplied with CANLUB coatings on all fuel elements.

In a fairly short time manufactures were able to increase CANLUB coating capacities, once production scale coating and baking facilities were procured and installed. Overtime the CANLUB coating process at the manufacturers has remained almost unchanged, although production capacities and productivity have increased considerably with process automation and various degrees of robotization for material handling.

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6th International Conference on CANDU Fuel
Selected Abstracts

Ed. Note: To provide some flavour of the range of papers presented, we reprint below a few abstracts from the 70 papers presented at the 6th International Conference on CANDU Fuel held in Niagara Falls, Ontario, September 26 to 29, 1999. The selection has been arbitrary. Proceedings of the conference, with full papers, will be available from the offices of the Canadian Nuclear Society.

Load-Following Performance and Assessment of CANDU Fuel

by M. Tayal, M. Floyd, D. Rattan, Z. Xu, A. Manzer, J. Lau, Atomic Energy of Canada Limited, Ontario Canada and E. Kohn, Ontario Power Generation Incorporated, Ontario, Canada

Abstract

Load following of nuclear reactors is now becoming an economic necessity in some countries. When nuclear power stations are operated in a load-following mode, the reactor and the fuel may be subjected to step changes in power on a weekly, daily, or even hourly basis, depending on the grid's needs.

This paper updates the previous surveys of load-following capability of CANDU fuel, focusing mainly on the successful experience at the Bruce B station. As well, initial analytical assessments are provided that illustrate the capability of CANDU fuel to survive conditions other than those for which direct in-reactor evidence is available.

Conclusions

Operational feedback from 3 Bruce B reactors shows no evidence of fuel failure from SCF for up to 3 reactor power manoeuvres per week for 9 months. Fuel irradiation experience from the research reactors is also encouraging. Initial analytical assessments for SCF show that fuel would survive more frequent load-following operation, albeit with reduced margins to failure. Thus CANDU fuel continues to show good performance in base-load and in load-following modes of operation.

Joining Technology Development for PHWR Fuel Assemblies in India

by Pankaj B. Desai and P.G. Kulkarni
Bhabha Atomic Research Centre, India

Summary:

PHWR fuel assemblies are fully welded structures. Several modern joining techniques are being used in India for welding Zirconium alloys for these assemblies. Many intricate geometries have been successfully welded to a high degree of quality and integrity. Developments are carried out for appendage welding and end closure welding. Modern equipment and techniques are utilized to improve the weld quality, increase production rate, reduce rejection rate and improve reliability. Laser, EB, GTAW and pulse magnetic welding are evaluated in addition to resistance welding. Weld strength, clad collapse, metallography and corrosion tests have been rigorously carried out to comply with specifications. An automatic welding system concept has been designed for spacers welding on empty clad tubes for required production rate.

Advanced techniques in resistance welding, controls and on-line monitoring are being utilized to improve quality and reliability in fuel assemblies. Appropriate quality control plans have been worked out to ensure the weld quality and consistency. Some of the weld monitoring system such as Dynamic Resistance, Weld displacement has been successfully developed to assure, non-destructively, the weld quality. Work on advanced techniques such as Acoustic Emission, ultrasonic tests etc are being pursued for weld monitoring applications. Welding technologies have been developed to meet the requirements of fuel assemblies fabrication for Indian PHWR power program.

Fuel Performance at Cernavoda Unit #1

by Dan Stanila, Reactor Physics and Core Performance Group CNE-PROD

Abstract

This paper presents the fuel performances achieved during the first two years of commercial operation.

After two years of commercial operation, the fuel performance at Cernavoda Unit-1 is within the normal limits:

- the rate of fuel defects is small (less than 1 defective for 1000 irradiated bundles);
- the average fuel discharge burnup achieved is ~ 156.5 MWh/kgU;
- the activity of the fission products in the coolant was at, a low level throughout the period, well below the license limits;
- defective bundles have been discharged without any difficulty.

Technical Aspects and Benefits of The Use of RU in CANDU Reactors

by H.C. Suk, J.H. Park, B.J. Min and K.S. Sim, Korea Atomic Energy Research Institute
W.W. Inch, Atomic Energy of Canada Limited, Chalk River Laboratories
T.G. Rice, British Nuclear Fuel plc

Abstract

The use of recovered uranium (RU) in CANDUs is an excellent example of the environmental 3R's (Reduce, Reuse, Recycle) as applied to global nuclear energy use. RU fuel offers a very attractive alternative to the use of natural uranium (NU) and slightly enriched uranium (SEU) in CANDU reactors because fuel economy is expected to improve even more through the use of RU. RU, with about 0.9% ^{235}U enrichment, results in an average discharge burnup of about twice that of NU in a CANDU reactor, thereby increasing resource utilization and reducing fuel requirements. Spent fuel volumes and fuelling costs are reduced. Therefore, the use of RU in CANDU reactors potentially offers economic, environmental and public acceptance benefits on both the front-end and back-end. These benefits all fit well with the PWR-CANDU fuel cycle synergy. RU also offers greater flexibility in reactor and bundle designs and a power uprating capability. RU fuel can be packaged in the CANFLEX fuel bundle, since the full benefits of the use of RU in CANDU reactors are achieved through the provision of enhanced margins in the bundle design.

RU, like NU and SEU, is a nuclear fuel commodity available from several sources. The cumulative quantity of RU projected to arise by the year 2000 from the reprocessing of spent oxide fuel in Europe and Japan is approaching 25,000 te. This quantity would provide sufficient fuel for 500 CANDU-6 reactor years of operation. Security of supply is, therefore, not an issue, and in addition, SEU of equivalent enrichment can be always be substituted for RU. It is anticipated that using RU in CANDU reactors will provide improvements in fuel cycle economics.

The suitability of RU as a reactor fuel for CANDU has been studied in KAERI and AECL: CANDU fuel fabricated from RU meets CANDU specifications; utilizing RU does not introduce serious radiological difficulties, and no special precautions or technologies are required for handling of RU fuel bundles; hence new fuel receipt and management at reactor is particularly simple. Under current legislation and practice, it is also recognized that there are no obstacles to international or domestic transport of commercial quantities of RUO_2 powder.

A Reactor Physics Study of the Economic Penalty associated with LVRF and Increased Pressure Tube Thickness

by Daniel Rozon and Wei Shen, Institut de Génie Nucléaire, Ecole Polytechnique de Montreal

Abstract

Both the pressure tube (P/T) life and coolant void reactivity are essential factors in the design of CANDU reactors. In this paper, we report on a reactor physics study of the economic penalty associated with solutions related to these factors, i.e. increased pressure tube thickness and the use of burnable poisons. Natural uranium (NU), 0.9% and 1.2% slightly enriched uranium (SEU), and mixed-oxide (MOX) fuels were compared for an advanced 43-element CANFLEX geometry bundle design. Our calculations show that the burnup penalty associated with a 25% increase in P/T thickness for NU is of the order of 14%, which represents well over one million dollars every year in a CANDU 6 reactor. On the other hand, the same increase in tube thickness for a CANDU 6 fuelled with 1.2 w/o SEU fuel (using a 2 bundle-shift) yields a penalty of only 3.1%, or a few 100k$'s per year. This very large reduction in the burnup penalty for the same pressure tube thickness increase illustrates the fact that slightly enriched fuel in CANDU is superior to natural uranium in terms of neutron economy.

Another significant advantage of using enriched fuel in CANDU is the possible development of Low Void-Reactivity Fuel (LVRF). Previous studies have shown that void reactivity in a CANDU reactor can be reduced or even eliminated by adding an appropriate amount of neutron poisons mixed with depleted uranium in the inner elements of the CANDU fuel bundles. However, this can only be achieved with enriched fuel. In order to estimate the cost associated with the introduction of LVRF in CANDU, we compared the effect on void reactivity and discharge burnup of various quantities of a burnable poison (Gd) and of a more permanent poison (Dy). The burnup penalty was defined relative to the performance of unpoisoned fuel with the same fissile content. We found a burnup penalty of approximately 1000 MWD/t(U) for each mk reduction in core void reactivity, regardless of the type of poison used in the design. All the calculations in this study were carried out by the DRAGON/DONJON chain of codes with Winfrith 69 groups library.

Five Years of Successful CANDU-6 Fuel Manufacturing in Romania

by A.C. Galeriu, A. Pascu, G. Andrei, A. Bailescu, S.N. Nuclearelectrica S.A. - Fabrica de Combustibil Nuclear

Abstract

This paper describes the evolution of CANDU-6 nuclear fuel manufacturing in Romania at FCN1 Pitesti, after the completion of the qualification in 1994. Commercial production was resumed early 1995 and fuel bundles produced were entirely delivered to Cernavoda Plant and charged in the reactor. More than 12,000 fuel bundles have been produced in the last five years and the fuel behaved very well. Defective bundles represents less than 0.06% from the total irradiated fuel, and the most defects are associated to the highest power positions.

After qualification, FCN focused the effort ti improve braze quality and also to maintain a low residual hydrogen content in graphite coated sheaths.

The production capacity was increased especially for component manufacturing, appendages tack welding and brazing. A

new graphite baking furnace with increased capacity, is under design. In the pelleting area, a rotary press will replace the older hydraulic presses used for pelleting.

Plant development will take into consideration the future demands for Cernavoda Unit 2.

Post-Irradiation Examination of Two Gentilly-2 Bundles to Investigate the Effect of Pressure-Tube Diametral Creep on Fuel Performance

by Z. He and M.R. Floyd, Atomic Energy of Canada Limited, Chalk River Laboratories

Abstract

Two bundles, discharged in 1997 from the Gentilly-2 Nuclear Generating Station, were selected for post-irradiation examination to investigate the effect of pressure-tube diametral creep on fuel performance. The bundles were irradiated in a pressure tube that had experienced relatively high diametral creep (maximum = 2.5%); these operated at peak outer-element linear powers of 48 and 52 kW/m to bundle-average burnups of 179 and 163 MWh/kgU, respectively.

Bundle orientation in the channel was determined from bearing-pad wear marks on individual elements. Residual sheath strain, fission-gas release and UO2 grain growth were measured on elements located at the top and bottom of each bundle. All observed performance parameters were within the expected range, and there was no apparent difference between elements irradiated at the top and bottom of the bundle/channel. It is concluded that pressure-tube diametral creep had no measurable impact on the performance of these bundles.

Call For Papers

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McMaster University, Hamilton, Ontario
March 2000

Students are invited to submit papers reporting their work. The contributed papers will be published in a bound conference proceedings and made available to attendees. Papers must be submitted in camera-ready format. Topics to be covered in the conference include, but are not limited to, the following nuclear related disciplines:

Nuclear Safety; Radiation and the Environment; Reactor Physics; Simulation / Numerical Methods; Thermalhydraulics; Nuclear Systems and Technology; Nuclear Medicine; Waste Management; Fusion Science and Technology; Applications of Radiation and Radioisotopes; Nuclear Chemistry; Nuclear Instrumentation; Nuclear Materials; Fuel Cycles; Irradiation Processes and Food Irradiation; Reactor Control and Instrumentation; Information Technology

Format of Papers:

Papers may be in French or English, 2-5 pages long without page numbering. Text should be typed single spaced on 8-l/2 x 11" paper with 1" margins on all sides. The first page should include the title of the paper, author(s) name, affiliation and complete address. The recommended font is Times Roman 12 point. References should be listed at the end of the paper.

Presentations:

Presentations may be in French or English with a maximum duration of 15 minutes, followed by a 5 minute question period. Overhead and slide projectors will be available. Other audio-visual equipment will be made available.

Submission Deadlines:

Notice of Participation: A "Notice of Participation" form should be completed by all participants, whether presenting or not (including non-student participants) and mailed or faxed no later than January 15, 2000.
Papers: To be included in the Conference Proceedings, papers should be mailed to the Conference Chair no later than February 16, 2000.

Contact:

Dr. Bill Garland, Professor, Dept. of Engineering Physics
McMaster University, 1280 Main Street West, Hamilton, Ontario, Canada, L8S 4L7
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The future of nuclear energy in Canada - a report on a conference

Excellent speakers but relatively small attendance would be one description of the ***Conference on the Future of Nuclear Energy in Canada*** held in Ottawa, September 30, October 1, 1999. Despite the many uncertainties facing the Canadian nuclear program the number of representatives of the Canadian nuclear industry was surprisingly small.

Organized by Bruce Doern and Bob Morrison of the *Carleton Research Unit on Innovation, Science and Environment (CRUISE) of Carleton University,* the conference presented an impressive list of speakers who covered almost all of the issues surrounding nuclear energy in Canada. There were four sessions, devoted to: the International Context; the Canadian Context; the Provincial and Regional Context; and, Environmental Implications. In each area senior and knowledgeable speakers presented insightful and sometimes controversial comments on a particular aspect of the overall problem.

Bob Morrsion set the scene with a masterful overview paper, providing concise observations on the changing political and social environment over the past decades and summarizing the main challenges that governments and the nuclear industry must address. *(His paper is reprinted in this issue of the* CNS Bulletin.*)*

Bill Hancox, V.P. Marketing, AECL, characterized the international markets for nuclear power plants as "thin". The competition from combined cycle gas turbines is extreme. However there are some brighter spots. Korea and China continue to be interested in CANDU and the possible fuel cycle synergy with LWRs. He commented that safety is very important for China which has a policy that there should be no evacuation necessary even for the worst credible accident.

Two speakers from the uranium industry, Gerald Grandy of Cameco, and Arnaud de Bourayne of Cogema gave their perspective on the future of nculear power and the state of the uranium industry. The current price of uranium is only about 1/4 of that 15 years ago. If uranium production is to continue, Grandy said, three issues must be addressed:

- regulatory overlap and duplication
- oppressive taxation
- leadership

On the last point he argued industry and governments must work together to solve the spent fuel issue, adopt an energy policy which recognized nuclear, and, promote international cooperation.

Linda Gunter, from the Nuclear Energy Institute of the USA, claimed there is a "nuclear renaissance" in the USA. Safety and economic performance of nuclear plants are at an all time high; the issue of "stranded costs" has been resolved; and, the USNRC is moving to "risk informed" regulation. She stated that there is even talk of new nuclear plants.

In contrast, Steve Thomas of the University of Sussex, UK, stated that the nuclear program in the UK was "textbook case of how not to make public policy".He predicted that there would be no new nuclear plants in the UK for the foreseeable future.

Setting the Canadian Context, Michael Cleland, Assistant Deputy Minister, Energy, Natural Resources Canada (NRCan), spoke of a "multi-fuel economy". While noting that a large proportion of greenhouse gas (GHG) emissions come from the energy sector and those could be minimized by further use of nuclear power, many objections remain against nuclear. The "market" will meet most [government] policy objectives, he said, but it is "difficult to see [GHG] reductions to meet the Kyoto protocol without nuclear". Noting the challenges of competition and public acceptance he concluded, "getting there will be tough".

To a question later, Cleland said that the Prime Minister had stated there would be no "carbon tax", but that the government would be looking at other "mechanisms" to achieve the GHG goals.

Mark Gwozdecky, newly appointed Director, Nuclear Non-Proliferation and Disarmament Implementation Agency of the Department of Foreign Affairs and International Trade, outlined Canada's non-proliferation policies and the country's role in international cooperation. He commented briefly on the program to study burning MOX fuel in CANDUs as a "constructive role in assisting in the disposition of stockpiles of weapons grade plutonium".

An overview and critique of the Canadian nuclear regulatory system was presented by David Jackson, formerly with AECL, now a professor at McMaster University. He noted the AECB's move to a more "compliance based" regulatory approach in contrast to its earlier performance or risk based approach now being adopted by the USNRC. This has brought complaints from the industry, he noted, but asserted, "credible and effective regulation is essential to the survival of nuclear activities in Canada".

Mark Ronayne, of the federal Competition Bureau, noted that in the past there was very little inter-provincial trade in electricity. He commented that a competitive market needs a strong control authority. Much of the needed rules are in place in Ontario, he said, while Alberta (the other province actively moving towards a competitive electricity market) is following an "evolutionary" approach.

Sylvana Guindon, of the Nuclear Division of NRCan, presented the paper co-authored with Brian Moore, director of the division, on the competitiveness of nuclear energy. (This was essentially an update of the paper they presented at PBNC 10 in Banff in 1998.) While noting the current strong competition of coal and gas she commented that the cost of generation by these sources was very sensitive to their cost.

The Provincial perspective was presented by Rick Jennings, Director, Energy Policy Branch, Ontario Ministry of Energy, Science and Technology, who reviewed the restructuring of the electricity supply industry in Ontario. A competitive market, he sais, "imposes a new set of risks and rewards, forces a rigorous and ruthless evaluation of decisions, and is very cognizant of bottom line impacts and judgements". On the restarting of Pickering A and Bruce A plants he stated, "decisions... must be made on a commercial basis that include all costs and risks".For the future, he commented, "market prices will be a key input in investment decisions". "The next few years should be an immensely exciting and interesting time to be in the generating business", he concluded.

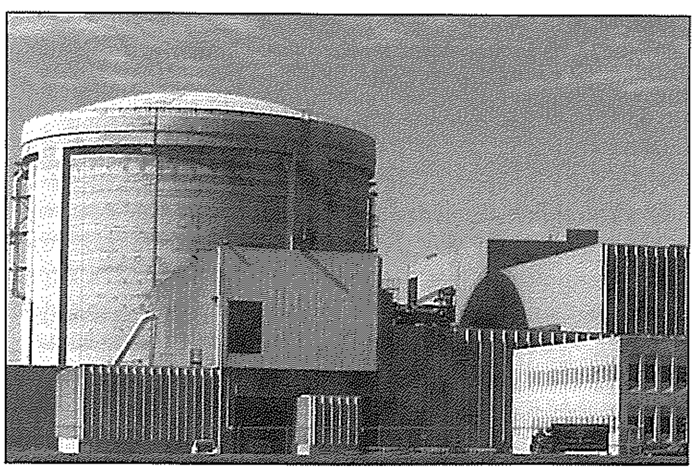
Patrick McNeil, V.P. Corporate Development, Ontario Power Generation Inc.,provided his company's view on the future of Ontario's nuclear program. After reviewing the current status of OPG he commented that "successful nuclear is key to OPG's success". He identified four "pillars" essential for commercial viability:

- safety
- regulatory acceptance
- community acceptance
- profitability

and expanded on each. He noted that the province expected OPG to produce a 14% profit. Nuclear is very competitive, he said, before re-investment is needed but re-tubing, re-boilering, and life extension are major challenges.

Donald Dewees, professor in the Department of Economics, Faculty of Law, University of Toronto, predicted that the wholesale price for electricity in Ontario for the next few years would be close to the 3.8 c/kWh cap set by the province for OPG. He also considered it unlikely that there would be any tax on air pollution from fossil plants.

Stephen Probyn, whose company has been involved in several non-utility generation projects, emphasized that "in the open market no one looks beyond five years". Referring to possible limits on GHG emissions he noted that the USEPA had "grand fathered" old coal fired plants. He argued that regulatory agencies, such as the AECB and CEAA, must adjust to the new market time frames.



Point Lepreau NGS.

Conference co-organizer Bruce Doern reviewed the re-structured Ontario Energy Board, noting it was still in a transition period. He outlined the challenges facing the OEB as it moves to being a "multi-functional, performance-based regulator" It is "likely to become the *de facto* economic regulator of nuclear power", he suggested.

The session on Environmental Implications began with a presentation by Stuart Smith, chair, National Roundtable on the Environment and Economy, an advisory group to the federal government. He acknowledged that the term "sustainable development" was undefined and, he asserted, undefinable. Nevertheless it is a concept that has become pervasive. "The competitive market is not good for the environment" he opined and suggested that the USA is unlikely to ratify the Kyoto protocol.

Stating a personal belief in nuclear power, Smith identified three requisites for its future:

- costs must be reduced
- a carbon tax or similar action is needed
- public perception [of nuclear] must be improved.

On the last point he urged for full openness. The major factor, he said, is trust (or lack of it).

Peter Brown, Director, Uranium and Radioactive Waste Management Division, NRCan, gave an update on the nuclear fuel waste issue. *(See his paper in this issue of the* CNS Bulletin.*)*

Ken Nash, V.P. Waste Management, OPG, reviewed his company's position and actions in light of the EARP Panel report of 1998 and the government's response. OPG has set up a separate fund and is looking into a possible structure for a Waste Management Organization (WMO). Canadian utilities need a "level playing filed" with the USA he stated. The future of nuclear power, he opined, is linked to the waste issue and building public and shareholders confidence is essential.

In the open discussion there was brief mention of the initiative to identify "green energy" sources and allow electricity marketers to charge more for electricity alleged to come from such sources. (Among those promoting such a move "nuclear" is not "green".)

The question was raised of on-going support of research and development given the economic pressures of the market. Peter Brown and Ken Nash were non-commital about the amount of nuclear waste disposal technical capability could be retained over the period likely to be taken to establish a functional WMO. Other speakers acknowledged that the market forces now in play would likely limit utility support for R & D to that directly required for their operations.

Organizers Bruce Doern and Bob Morrison reported that they would be producing a book based on the conference which would be published in about a year's time.

The Future of Nuclear Energy in Canada An Overview

by Bruce Doern and Robert Morrison[1]

***Ed. Note:** The following is a slightly edited version of the paper presented by Dr. Morrison as the introduction to the CRUISE Conference on The Future of Nuclear Energy in Canada, held in Ottawa, September 30 - October 1, 1999.*

Recent Developments

The future is always interesting, regardless of the topic, but a series of recent and impending developments in nuclear energy provide good reasons for a review now. Partly there is an opportunity for interested people - from universities, governments, and the private sector - to catch up with events and share their impressions. But there is also a need to look at the implications of these events for critical policy and investment decisions that will be taken in the near future.

International

Nuclear power programs everywhere are facing a situation where they will either grow, plateau, or phase out over the next two decades, as the first big generation of nuclear power plants come to the end of their planned lives in that period. Strong pressures push in each direction, the outcome is uncertain, critical decisions must be taken, and the consequences are far from trivial. Governments have a keen interest in the outcome, and will be important in determining it.

The role of governments in the energy sector is changing, with government financial support for nuclear energy decreasing and market forces becoming more determinant. But broader government policies on R&D, on climate change, on the management and regulation of risk, and on public processes will still have a strong influence on the future of nuclear energy.

Electricity, along with transport, is one of the growth areas in the global energy sector. It represents about 37 per cent of primary energy already. Its sources are 65 per cent fossil, and 17 per cent each for nuclear and hydro. The world is turning increasingly to high-quality forms of energy. Electricity fits this bill admirably: versatile, flexible, convenient, fundamental to the information economy, clean at the point of use and at the source as well for nuclear and non-carbon renewables. The world as a whole is expected to require about 2900 GW of new generating capacity from 1995 to 2020, doubling the total, and 600 GW of replacement capacity.

Energy and electricity growth will be faster in developing countries than in the OECD countries. The poorest 20 per cent of the world's 6 billion people consume 3 per cent of the electricity, and many have no access to it at all. Under a business as usual scenario, electricity demand is expected to grow at about 5% in developing countries, so the main market for new generating capacity in the next two decades will be there. Given the inertia of energy systems, decisions by developing countries over this period will have a strong influence on the structure of world electricity energy supply for many years beyond *(World Energy Outlook, IEA, 1998; Global Energy Perspectives, IIASA/WEC, 1998).*

Nuclear programmes will grow, plateau, or phase out . . . the outcome is uncertain.

Electricity markets in the world and in Canada are being restructured to encourage competition. Natural gas combined cycle plants are dominating the market for new generating capacity. At the same time, concerns about climate change and air quality will restrict fossil fuel emissions. The size and scope of those restrictions will be important for nuclear energy.

Existing nuclear plants can make a significant contribution to electricity supply and to emission reductions to the end of their planned lives, and beyond, through plant life extension. Many can compete effectively on operating, maintenance and fuel costs, although some will not recover their full stranded costs, and some will be forced to close *(Gonzalez, European Seminar, 1999).* Their performance over the next decade will determine the possibilities for plant life extension and set the stage for decisions about new and replacement capacity, largely on straight economic grounds: nuclear, fossil or renewables? If nuclear, will the designs be evolutionary or revolutionary?

National

In Canada, the market for new nuclear plants, and for large scale baseload capacity generally, dried up in the 1990s. The same is true for most of the OECD countries with nuclear power programs. This puts the near term domestic focus on running existing plants well - safely and economically - rather than

{1} Drs. Morrison and Doern are with the Carleton Research Unit on Innovation, Science and Environment (CRUISE) of the School of Public Administration at Carleton University, Ottawa. They organized the two day conference on the Future of Nuclear Energy in Canada.

The government faces major [nuclear] policy decisions.

building new ones. The domestic market may not return for some time.

Meanwhile the market in emerging economies picked up. Atomic Energy of Canada Limited (AECL) obtained three CANDU orders in Korea and then two in China, with the potential for more sales to that country's ambitious nuclear programme. The Asian projects have gone well. In a globalizing economy, a Canadian high-tech product with a market in fast-growing Asia provides a rationale for support of its own. But financing a series of CANDU sales, even at commercial rates, will be a challenge. AECL will need follow-up orders to keep going, and improved designs in order to compete effectively in the medium term.

In the 1995 Program Review, the Liberal Government reduced AECL's funding, while maintaining AECL's mandate to be the leader of the Canadian nuclear industry as a fully commercial CANDU-oriented business, a major shift from its origins as a national R&D agency. AECL once supported a broad range of nuclear R&D, including basic science. Now it must concentrate on the R&D for the CANDU system. A new research reactor is needed to maintain continuity of support for CANDU and supply neutrons for basic science research. It would mark a renewal of Canada's long tradition of excellence in nuclear science.

The Canadian uranium and radioisotope isotope businesses, now in private sector hands, have resolved a number of recent challenges and look set to continue as profitable, largely export-oriented businesses, in each of which Canada is the world leader. Isotopes from Canada play important roles in industrial sterilization and in medical diagnosis and therapy. They are used for over 12 million medical procedures every year worldwide *(Malkoske, CNA, 1999).*

The Government of Canada faces major policy decisions involving nuclear energy in the context of its longer term approach to energy and environment issues. As might be expected, most of these decisions involve money and the public policy rationale for spending it, whether on R&D, export financing, or waste management.

Nuclear energy is an important trade and foreign policy issue for Canada. It is one of the few high tech areas where we enjoy a trade advantage. To export nuclear materials, equipment and technology, Canadians need to be assured that they are used only for peaceful purposes. Canada has been a leader in non-proliferation policy since its reaction to the Indian explosion of 1974. It continues to maintain strict non-proliferation policies and to participate in international activities designed to restrict diversion of nuclear technology from peaceful to military uses.

In the 1990's, additional concerns have arisen internationally about clandestine weapons programs, and about the diversion of materials on their way out of the military sphere. The dismantling of nuclear weapons by the weapons states means that weapons-suitable material removed from warheads must be secured and rendered unuseable, or significantly less useable, for explosive purposes. Highly enriched uranium can be converted to low-enriched uranium and used as fuel. This process has become an important factor in the nuclear fuel market. For plutonium, the issues are more sensitive, because it is relatively less difficult to separate from mixtures. One approach is to incorporate the plutonium in low concentrations in nuclear fuel (mixed oxide fuel or MOX). Civil plutonium is already widely used in this way in Europe. Burning this fuel in reactors renders the remaining plutonium much less accessible for weapons purposes. Canada has offered to carry out some tests for CANDU fuel, a move that has engendered some controversy *(Gizewski, Toronto, 1997).*

Regulation for health, safety and environment continues to be a core function of government, The Atomic Energy Control Board will be operating under new legislation, and a new name. *(Bishop, CNS, 1999)* It faces the challenge of dealing with ageing plants in a competitive marketplace. It will have to identify and monitor indicators that measure the commitment of the senior management of nuclear facilities to a safety culture. Nuclear safety will continue to be a key factor in public and political support for nuclear energy in Canada and abroad, and effective regulation is an essential contributor to safety.

Nuclear liability legislation in Canada for third-party damages from severe accidents should be brought up to date soon, further internalizing the costs and risks of nuclear energy in line with international practice. Meanwhile other human activities, from smoking to chemicals, and indeed fossil fuels, are under increasing pressure to deal with liabilities for longer term and accidental impacts.

The federal government also has an interest in the regulation of the economic power in the market. In competitive markets, the economics of nuclear energy will be decisive in determining its role. Investments in new generating plant or in refurbishment will be decided on the basis of their return, under the prevailing regulatory requirements. Nuclear energy will have to survive in the short term in order to contribute effectively in the long term. Comparisons of alternatives, and decisions about them, depend a great deal on what factors are included and on what weight is assigned them.

Provincial

In Canada, nuclear energy falls under federal jurisdiction, and electricity under provincial. Many of the important decisions on nuclear energy are made by the provinces, especially Ontario, which has most of the nuclear industry, R&D, and generation in Canada.

In the mid-1990's Ontario Hydro's management problems began to affect performance, and to raise longer-term concerns about their potential impact on safety. The CANDU technology was not called into question, but new management was brought in with a mandate for extensive change in the nuclear operations. At the same time, the Ontario government moved toward the opening of the electricity sector to competition.

The Ontario Government has made some bold decisions recently on the structure of the electricity sector in that province, introducing competition but leaving Hydro's generation facilities together, and under public ownership, at least for now *(White Paper, Ontario, 1997)*. Cost and service are seen as fundamental, and best obtained through competition. Security and reliability of supply are seen as concerns that the market will look after. Ontario Hydro's nuclear division has gone through a major reorganization that will largely decide the fate of nuclear power generation within Canada over the next few years. Hydro's successor company for generation, Ontario Power Generation, or OPG, is looking at its overall role in the North Eastern North American market, while working to bring the 12 operating plants back up to high and sustainable levels of performance *(Osborne, CNA, 1999)*. It will soon face decisions about the restart of the Pickering A and Bruce A plants, about reducing it's control of Ontario's generation resources, and about its management of wastes.

Sustainable Development Implications

One important current consideration for nuclear energy is its potential contribution to sustainable development, notably to climate change and air quality objectives. The Canadian Nuclear Society is holding a conference on Nuclear Energy and Climate Change in Ottawa in November.

Sustainable development principles require the minimization of burdens passed on to future generations, and the maximization of options for them. These principles will have to be integrated into upcoming decisions about moving into a more operational phase on different kinds of radioactive wastes. This follows a long period of public consultations on radioactive wastes, culminating in the report of the Environmental Panel on the Nuclear Fuel Waste Management and Disposal Concept, and the government's response, the outcome of the joint federal/provincial panels on new uranium projects in Saskatchewan, and the work of the Siting Task Force on historic low level wastes in Ontario. Ontario Power Generation and other owners of nuclear fuel waste are setting up a dedicated organization that will attempt to make progress on nuclear fuel waste management issues, building public confidence, looking at the relative weight to be assigned to long term storage and permanent disposal, and developing a process for site selection. Progress on radioactive waste management, along with reactor safety and non-proliferation issues, is one of the key issues to public acceptability.

Public Policy Issues and Rationales

Nuclear energy has been fostered by governments, often though government agencies. In Canada, nuclear energy was developed by federal and provincial Crown Corporations in Canada over the postwar decades, when government leadership in science was considered the best way to go, given its success in wartime. Nuclear energy is a unique example of the rise and decline of government intervention in the economy and in direct efforts to advance science and technology (S&T) through government laboratories. Because of its strategic and energy implications, nuclear energy has been dealt with by governments as a special activity at the highest level.

The amount of support going into nuclear energy through government auspices meant that it was also used to serve other purposes: national prestige, technical assistance, regional development and employment, industrial development, federal/provincial relations. In some cases this has distracted efforts from the main developmental focus.

As governments withdraw in favour of market forces, the nuclear energy sector is undergoing major changes, but, as noted, the evolving role of governments will still be critical. Processes that involve the public will be increasingly important, as public acceptability will be one of the key issues for the future of nuclear power.

Other public issues that involve nuclear power, but go well beyond it, are the provision of science advice to governments, and the management and communication of risks across the entire spectrum of human activities, and the related issue of valuing and comparing health and environmental risks and benefits.

After looking at recent developments, and before looking to the future, its interesting to note the changes in rationale for the support of nuclear energy over the years, and the degree of government involvement. *(Morrison, NRCan, 1998)*. Canadian governments, both Liberal and Conservative, have consistently supported nuclear energy, but for different reasons and to different degrees at different times.

1942 - 57

Initially it was simple: nuclear fission was discovered in 1939 in a time of crisis, and Canada's interest was to contribute to the war effort, by supplying both uranium and plutonium, and to build research capability in an important new industrial sector. Canada had very little industrial research at that time, and the idea was to get into it through a new field rather than try to compete in established industries. It was a clear attempt to pick a winner.

In the 1950s the federal and Ontario governments, through AECL and Ontario Hydro, made a concerted push toward a nuclear power generation capability through the CANDU reactor, a unique design using natural uranium and a heavy-water moderator. The goal was an economic, reliable and secure supply based on Canadian (read Ontario) technology and resources. Canada's uranium resources at that time were mainly in Ontario. Canada was also interested in exporting its nuclear technology, to assist developing countries and to create markets for Canadian goods.

The intent of the federal government was to have AECL do the R&D and turn over the design, engineering and marketing of reactors to the private sector. The government's uranium interests were also to be privatized. With the election of the Conservatives in 1957, this did not happen. AECL retained the reactor design, engineering and marketing functions, in addition to its basic and applied research activities. The private sector became suppliers of components and services.

1957 - 1980

Since 1965 Canada's nuclear programme, and its nuclear exports, have been for peaceful purposes only. The government intervened forcefully in the early 1970s to support the uranium industry and maintain price levels, after military demand vanished and before civilian demand took over The government's uranium interests were finally privatized in the late 1980s along with the radioisotope business that AECL had developed.

Ontario made a strong commitment to nuclear power in the 1960s and 70s, launching megaprojects which continued for 30 years with the construction of 20 large CANDU reactors, supporting both energy supply and industrial development for the province.

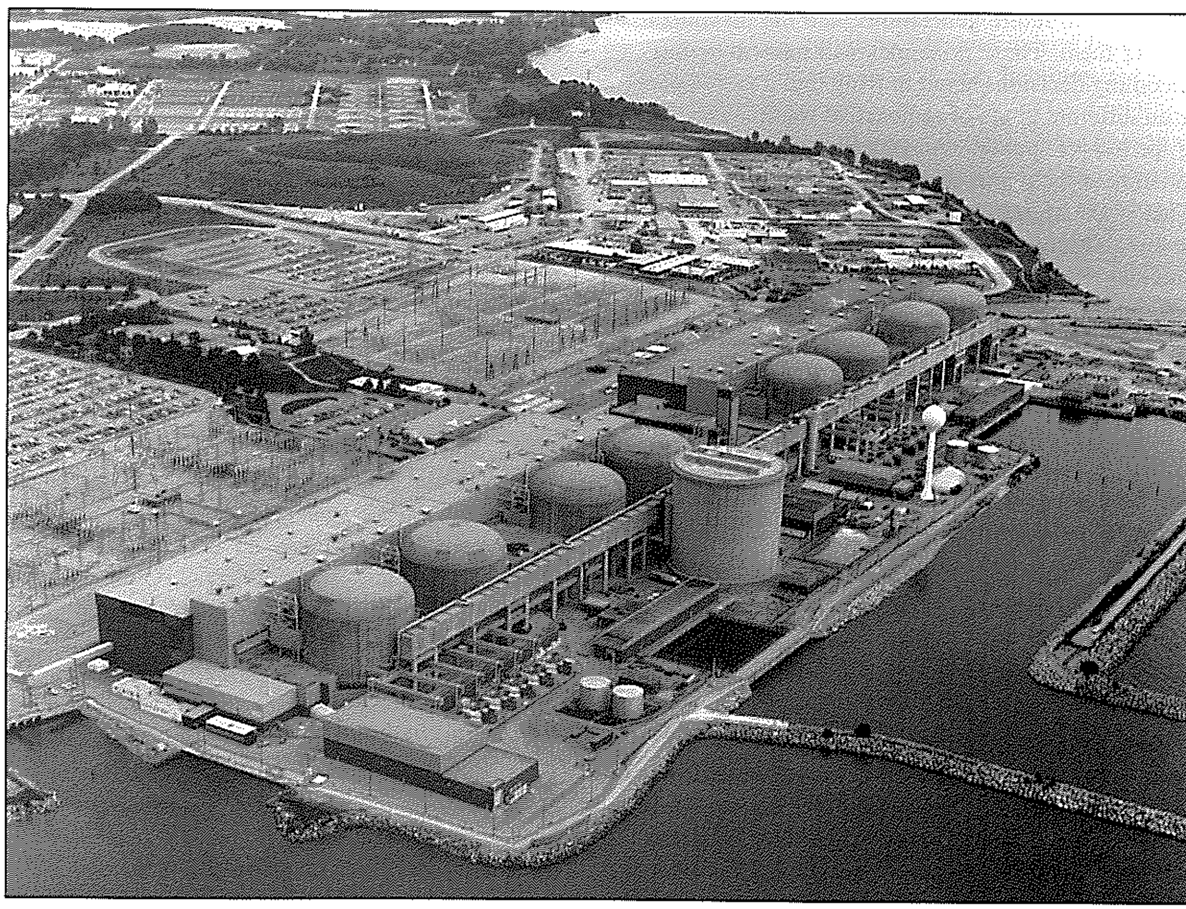
With the oil crisis of the 1970s, and concern about security and diversity of resource supply and about prices, nuclear energy became an attractive electricity source for many countries, and commitments grew rapidly. Canada's uranium resources, the benefits of a home-grown technology, and the economic and environmental advantages of nuclear versus coal, reinforced its appeal in this country.

Outside Ontario, Quebec and New Brunswick bought CANDU reactors, as did Argentina and South Korea. A substantial heavy water industry was created, at some public expense, and then dismantled a decade or two later when demand subsided. A nuclear fuel waste R&D programme was initiated to develop a disposal concept. The Indian explosion of 1974, using plutonium from Canada's gift of a research reactor, complicated Canada's nuclear export ambitions for several years. The government instituted stringent controls to counter the risks of nuclear proliferation.

A somewhat similar conference on nuclear policies took place in 1978 *(Doern and Morrison, IRRP, 1980)*. Many of the issues [identified then] are still with us but the context has changed. Oil prices were high and about to rise again. Coal-fired power was about 30 per cent more expensive than nuclear, and natural gas was considered a premium fuel that shouldn't be burned for the mundane task of generating electricity. The CANDU's in Ontario's Pickering A and Bruce A stations were performing well. Those outside Ontario were still under construction. Three Mile Island, and Chernobyl, with their stark lessons about nuclear safety, were still in the future. The Crown monopolies were secure.

1980 - 1993

The energy policy arguments for nuclear energy diminished in the 1980s as the price of oil, uranium and other resources fell, along with prospects for electricity demand growth. AECL sold



Pickering site, with four units of Pickering "A" NGS in foreground.

no CANDUs through the 1980s, but the prospect of further reactor orders for Ontario Hydro and for New Brunswick underpinned the rationale for government funding. The CANDU's in Ontario and elsewhere came on stream and performed exceptionally well, both technically and economically, regularly placing in the world's top ten reactors.

The Conservatives, elected in 1984, were primarily interested in dismantling the National Energy Plan, but they were wary of government intervention and Crown Corporations generally. While supportive of nuclear power, they thought it should be less dependent on government. They reduced AECL's funding, encouraged it to be more commercial, and declined to finance a CANDU sale to Turkey. Ministers asked, why not sell to countries that pay cash? And why not have Ontario, the main beneficiary, pay a larger share of the costs? AECL looked at a smaller CANDU 3 for the United States market, with new technology, but its introduction there proved to be problematic, and the technology was transferred to the larger reactor designs.

No sooner had AECL and Ontario Hydro, with the help of their governments, made an arrangement in 1990 for seven years of stable funding for AECL's R&D, than the election of an NDP government in Ontario brought a revised view of the industry's prospects. Ontario went into a recession, electricity demand stayed below its 1989 peak for seven years, Darlington was largely surplus when it came on stream, and the domestic market for new reactors vanished. Both AECL and Ontario Hydro underwent several years of turmoil in their executive offices. Ontario Hydro was downsized and became, for a while, a company more devoted to sustainable development goals than to the effective operation of its nuclear plants. Coal became more competitive with nuclear energy, and new natural gas technology looked like a good bet in times of uncertain load growth and regulatory change.

So, the government rationale for supporting nuclear energy in Canada has gone from military R&D and industrial development, to peaceful domestic electricity supply using Canadian technology and resources; the means [have changed] from strong government intervention to a much greater reliance on competition in the market. Nuclear power and other energy options must now be considered for government support on the basis of their contributions to broad public policy goals.

Sustainable Development

Sustainable development issues, and especially climate change, are attracting increasing emphasis internationally. The basic goal of sustainable development is to ensure that the future generations are no worse off, and ideally better off, than we are to-day, and that equity considerations prevail to a greater extent than they do now. This means that future generations should have more options than we have. Any loss of capital in the form of diminished resources or environmental burdens that we pass on should be compensated by other forms of capital such as the intellectual or social capital that we also pass on. Major options should not be foreclosed, and irreversible changes to basic life support systems should be avoided.

Nuclear energy is the most proven non-carbon source for large-scale, baseload electricity.

Nuclear energy is one of the great scientific discoveries of the 20th century. It creates a large new energy resource base from materials that were not resources before. It brings a unique technology and a different set of risks, so it contributes greatly to the diversity of energy choices. Because the cost of nuclear energy is largely in the technology, it should be amenable to significant improvement through R&D and through developments in information technology. Canada has played a significant role in the development of nuclear energy, and has acquired a unique experience and capability across the entire nuclear fuel cycle. This is a strong contribution to the pool of intellectual and human capital that we pass on to the 21st century.

From a sustainable development perspective, the ample resource base for nuclear energy, in which Canada's uranium industry plays a central role, and the possibility of extending it vastly through advanced fuel cycles, are important advantages for nuclear power in the longer term. But fossil fuels are also abundant for the next century and perhaps beyond, although their uneven distribution could lead to political restrictions on supply in some cases. Renewables also have significant potential for growth. Cost and availability of fuel resources at the front end of fuel cycles does not seem to be a major concern in the near term. The problem is more with the environmental impacts of the wastes products at the back end.

Canada and other countries are struggling to find ways of meeting their Kyoto reduction targets for greenhouse gas emissions. The energy sector is the biggest source of man-made greenhouse gas emissions, notably carbon dioxide. Electricity is a major contributor to those emissions, through the burning of fossil fuels. In a carbon-constrained world, non-carbon sources of electricity are one of the most promising options for longer term reductions in the growth of carbon emissions (World Energy Outlook, IEA, 1998). Transport is likely to remain carbon-based, although electricity from non-carbon sources is one possible alternative source of energy for transport.

Nuclear energy, with its effectively zero greenhouse and acid gas emissions, is the most proven and in many ways the most promising non-carbon source for large-scale baseload electricity, but it will have to compete in the short and medium term with other alternatives such as new renewables and efficiency gains. Air quality is also becoming an increasing health and environmental issue, and nuclear is a clean source from that perspective as well.

Detailed comparisons of external costs from different electricity fuel cycles *(ExternE, European Commission, 1995)* suggest that the major health and environmental impacts are those

It is important to get the message out about the benefits of nuclear energy.

from burning fossil fuels.. Natural gas is cleaner than coal or oil, and its use could greatly reduce air pollution, but it still has a significant greenhouse impact. Nuclear power has a much smaller overall impact than fossil fuels, even when the possibility of a severe accident is factored in.

The impacts from fossil fuels are a direct result of routine operations. While significant climate change is still not proven, there is no doubt about the increase of man-made greenhouse gas emissions, and the evidence of global warming related to them is mounting. Despite increasingly stringent regulations and economic incentives to restrict some emissions, large volumes of waste are discharged directly into the environment from fossil fuel burning. Many of the costs of fossil fuel emissions, including health costs from pollution and the potential impacts of climate change, are still external, that is, they are not included in the cost of fossil-fired electricity. Once discharged to the atmosphere, the waste products are no longer seen as the responsibility of the fossil fuel producing or consuming industries.

In routine operation under independent regulation, nuclear fuel cycle facilities seem to have very small external impacts. Wastes from the nuclear fuel cycle are relatively small in volume, and are largely contained as a matter of policy. The responsibility is retained. Wastes are carefully managed for both the short and the long term. Major impacts from nuclear energy would only result if something goes seriously wrong. Nuclear costs have been internalized to a large degree for normal operations, and are being increasingly internalized for accidents, through enhanced safety measures, tighter regulation, and liability legislation, and for waste management through incorporation in electricity tariffs.

Thus the comparison in impacts between fossil fuels and nuclear energy is largely between a potentially large, global long-term effect from routine emissions, whose costs are still largely external, and acute regional or local impacts through unlikely accidental releases of radiation, whose costs are increasingly internalized.

Public Acceptability

If climate change, and measures to mitigate it, are seen as critical to the future of mankind, such a comparison suggests that nuclear energy should be maintained and developed as an option, among others, to reduce the growth in greenhouse gas emissions from the world's expanding electricity sector. But many members of the public have different perceptions, seeing climate change as a far-off, diffuse eventuality.

For nuclear energy, the risks seems to be perceived as immediate, local, and dramatic, often linked to a specific local facility. People may be more concerned about the potential near-term negative impact on them than about its contribution to the future of mankind. They do not perceive the urgency of moving ahead with nuclear power when alternative energy sources and approaches to climate change appear to be available.

This underlines the challenge of public acceptability of nuclear energy generally *(Heriard-Dubreuil, European Seminar, 1999)*. It is important for the nuclear industry, and for concerned governments, to develop clear and forceful arguments for their activities and to get the message out about the near term and local benefits of nuclear energy. The one-way flow of information to the public may not be enough. And the issue may not be, how to gain acceptability for nuclear power, but rather how best to engage the public in developing a course for nuclear power that optimizes its contribution to broad public policy objectives?

Underlying public concerns is an issue of trust in institutions. This extends beyond nuclear energy to many areas involving risks to health, safety and the environment. People feel deeply about risks and want to be involved in a two-way communication process where their concerns are heard and addressed, not trivialized. Successful communication may depend as much on the mindset of the recipient as on the clarity and content of the message. This suggests we need to develop processes, consistent with our system of representative government, that build confidence and a sense of shared values by engaging people, listening to and addressing their concerns, giving them the information they want, and allowing them some say in the outcome. We have to do this in a way that balances the risk and benefits from across society's activities and doesn't just deal with individual risks in a piecemeal and isolated way.

There is a gap between expert knowledge and public perception in many areas. The institutions of government have not succeeded in filling that gap and have left it open for others, such as the media and special interest groups. If people know there has been a good debate, with all sides listened to and all reasonable options duly considered, they may be more inclined to accept the result. There would seem to be a new role for governments in managing, and communicating the risks involved in complex public policy issues in a consistent way.

Looking Forward

What are the challenges facing governments and industry with respect to nuclear energy in Canada now? The first is to decide about the medium-term role for nuclear energy, taking sustainable development concerns into account. Is it worth maintaining the CANDU option, and at what cost? How should different approaches to climate change goals be funded? How should the costs of carbon emissions be dealt with?

In our view, the nuclear option for Canada is worth maintaining, because of its resource base, its contribution to climate change and air quality goals, its high level of safety and low level of environmental impact under normal conditions, its amenability to improved safety and performance through R&D, and its cost of generating electricity, which represents a reasonable cap on the price level of electricity for the next century. The cost of maintaining the option will have to be carefully balanced against the benefits and against the alternatives.

Assuming a reasonably supportive stance, the key near-term objective for governments, utilities and the industry is to ensure that existing plants are operated safely and competitively, to renew the R&D infrastructure, and to make progress on waste management issues, including historic low level wastes. R&D to support existing plants and to move forward on fuel wastes should come largely from plant revenues. CANDU exports will be needed for AECL's survival in the vendor role.

For Ontario Power Generation, bringing the shut-down plants back on line and into good performance is a key goal. The adjustment to the new company structure and the new market structure in Ontario and in northeastern North America, and the setting up of a waste management organization, will occupy OPG for some years. Beyond that the utilities will face the question of life extension of the existing CANDU's or their replacement. Ontario does not yet seem to have paid much attention to the question of carbon emissions, but that should be a factor in considering the restart of existing plants, and in the decisions on life extension or replacement.

For the medium term, say 20 years, the objective is to have plans for plant life extension or new designs that will compete with the alternatives. Given the fundamental role of fossil fuels in the world economy, the nuclear industry should not hope for too high a value placed on carbon emissions. R&D support for these medium term goals could come in part from government, to the extent that it coincides with the government's policy goals.

In the long term, on the scale of a century or more, the objective will be to move towards advanced fuel cycles that extend nuclear fuel resources by orders of magnitude. These fuel cycles should be safe, competitive, and well proofed against proliferation.

In all these periods, the keys to the role of nuclear energy will be cost, under prevailing requirements for safety and environmental impact, and public acceptability.

The government will have an important role in nuclear legislation and regulation, and in addressing wastes and liabilities. Much of the work on wastes will be needed regardless of the future of nuclear energy. The government should also develop a coherent approach to the risks that society faces across a whole spectrum of activities, and to improve management, communication and public understanding of those risks.

The government will have to update its policy on non-proliferation to keep up with developments in this area, including new kinds of threats, new actions to counter or reduce them, and new opportunities to reduce tensions.

What does the future hold? Will nuclear energy in Canada and the world grow, plateau or decline? The answer partly with the utilities and their ability to manage existing plants safely and competitively and to plan their life extension, partly with the vendors and their ability to design new plants that will meet challenging cost and safety criteria, and partly with governments to move ahead on waste management, ensure effective regulation, decide the role that nuclear energy will play and manage the risks and benefits of different approaches to energy and environment issues.

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Nuclear Fuel Waste Policy in Canada

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Abstract

The 1996 Policy Framework for Radioactive Waste established the approach in Canada for dealing with all radioactive waste, and defined the respective roles of Government and waste producers and owners. The Policy Framework sets the stage for the development of institutional and financial arrangements to implement long-term waste management solutions in a safe, environmentally sound, comprehensive, cost-effective and integrated manner.

For nuclear fuel waste, a 10-year environmental review of the concept to bury nuclear fuel waste bundles at a depth of 500 m to 1000 m in stable rock of the Canadian Shield was completed in March 1998. The Review Panel found that while the concept was technically safe, it did not have the required level of public acceptability to be adopted at this time as Canada's approach for managing its nuclear fuel waste. The Panel recommended that a Waste Management Organization be established at arm's length from the nuclear industry, entirely funded by the waste producers and owners, and that it be subject to oversight by the Government.

In its December 1998 Response to the Review Panel, the Government of Canada provided policy direction for the next steps towards developing Canada's approach for the long-term management of nuclear fuel waste. The Government chose to maintain the responsibility for long-term management of nuclear fuel waste close with the producers and owners of the waste. This is consistent with its 1996 Policy Framework for Radioactive Waste. This approach is also consistent with experience in many countries. In addition, the federal government identified the need for credible federal oversight. Cabinet directed the Minister of NRCan to consult with stakeholders, including the public, and return to ministers within 12 months with recommendations on means to implement federal oversight.

Background

The federal government has legislative authority over the development and control of nuclear energy through the Constitution Act, 1867 (1), and the Atomic Energy Control (AEC) Act (2). The Nuclear Safety and Control (NSC) Act (3) which received Royal Assent in 1997 will replace the AEC Act and provide more explicit and effective regulation of the Canadian nuclear industry, including the management of "nuclear fuel waste" from a health and safety perspective. However, the NSC Act does not cover the broader federal oversight required for the long-term management, including disposal, of nuclear fuel waste.

Nuclear fuel waste refers to the nuclear fuel bundles discharged from 22 Canadian CANDU reactors. Twenty of these reactors are owned by Ontario Power Generation Inc. (OPG) and the other two are owned by Hydro-Québec and New Brunswick Power; most of Canada's nuclear power production began in the mid to late 1970s. The federal Crown corporation, Atomic Energy of Canada Ltd (AECL), has a small amount of waste from its prototype and research reactors. OPG thus has about 90% of the waste, the other two nuclear utilities about 8% and AECL 2%. Other waste producers and owners, such as universities, produce a small quantity of nuclear fuel waste (4).

About one million bundles of nuclear fuel waste are currently stored at nuclear reactor sites in Canada; 60 000 bundles are forecasted to be produced annually. The independent federal nuclear regulatory body, the Atomic Energy Control Board (AECB), considers that this nuclear fuel waste is presently stored safely and can continue to be stored safely for several decades. Nevertheless, the AECB has also indicated that, on health and safety grounds, a more permanent solution should be developed and that the goal is "disposal with passive institutional controls".

In 1977, the Minister of Energy, Mines and Resources engaged a group of experts led by Dr. Kenneth Hare to provide the Government and the public with views on nuclear fuel waste disposal. In their report the authors considered various waste disposal options and conclud-

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ed that the burial in geologic formations had the best potential for Canada. The Governments of Canada and Ontario formally accepted the proposal in 1978 and launched the Canadian Nuclear Fuel Waste Management Program. The Program involved the cooperative research and development efforts of AECL as the federal agent, and Ontario Hydro as the provincial agent. The development of the nuclear fuel waste disposal concept took place over 20 years at a cost of about $700 million, mostly funded by the federal government.

In 1988, the Minister of Natural Resources referred AECL's concept for deep geological disposal to the Minister of the Environment for a public review by an independent panel, pursuant to the Environmental Assessment and Review Process (EARP) Guidelines Order. AECL submitted its Environmental Impact Statement to the Panel in 1994 (4).

In 1996, the Government of Canada established its official Policy Framework for Radioactive Waste which covers all forms of radioactive waste including nuclear fuel waste, low-level radioactive waste and uranium mine and mill waste. The Policy Framework, developed in consultation with a broad range of stakeholders, states that:

- The federal government will ensure that radioactive waste disposal is carried out in a safe, environmentally-sound, comprehensive, cost-effective and integrated manner;
- The federal government has the responsibility to develop policy, to regulate, and to oversee waste producers and owners for ensuring that they comply with legal requirements and meet their funding and operational responsibilities; and,
- The waste producers and owners are responsible for the funding, organisation, management and operation of disposal and for other facilities for their wastes.

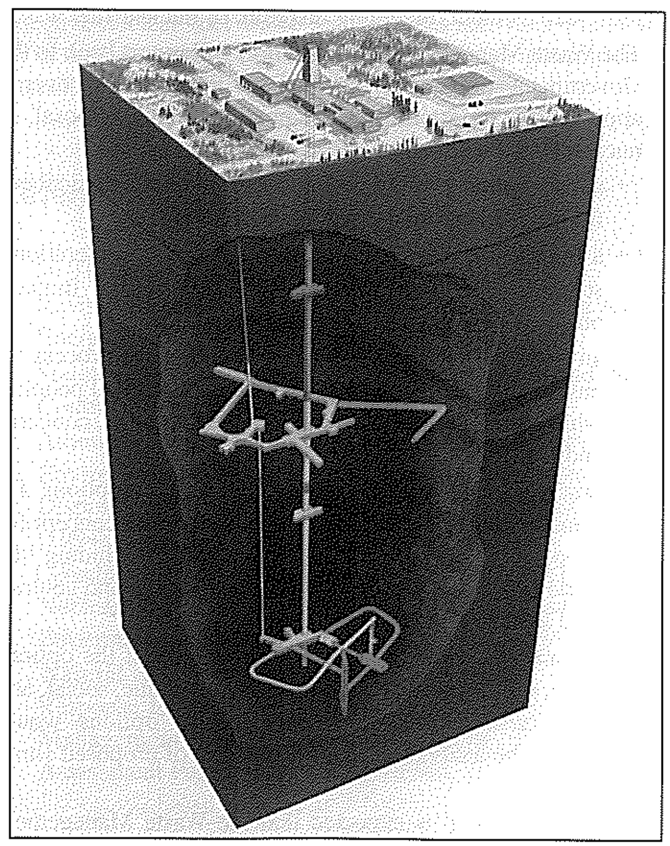
From March 1996 to March 1997, the EARP Panel held public hearings on AECL's deep geological disposal concept. This concept translates into a major undertaking which would cost about $10-13 billion over up to 70-100 years. The Panel released its report with conclusions and recommendations to the Government on March 13, 1998 (5):

- the Panel's main conclusion was that "from a technical perspective, safety of the AECL concept has been on balance adequately demonstrated for a conceptual stage of development but from a social perspective, it has not. As it stands, the AECL concept for deep geological disposal has not been demonstrated to have broad public support. The concept in its current form does not have the required level of acceptability to be adopted as Canada's approach to managing for nuclear fuel waste"; and,
- the Panel's principal recommendation was that "a not-for-profit corporation, perhaps formed by the utilities and subject to regulatory controls" be established "at arm's-length from the utilities and AECL", or that a new "Crown Corporation be created by federal legislation" to carry out Canada's nuclear fuel waste management activities which would be fully funded by waste producers and owners.

Reactions by stakeholders and the public to the Panel's conclusions and recommendations were varied; many were concerned that the disposal of nuclear fuel waste had received a severe setback.

The Government of Canada Response to The Earp Panel

In its December 3, 1998 Response, the Government of Canada reflected general agreement with most of the Panel's recommendations (6), including the establishment of a segregated Fund by producers and owners for long-term management of nuclear fuel waste. However, the Government of Canada response did not adopt the Panel's recommendation that a government organisation "at arm's length" be created to carry out future waste management activities. Consistent with the 1996 Policy Framework for Radioactive Waste, the Government placed the onus of responsibility with the producers and owners who profit from the operation of the nuclear reactors, produce the waste, and have first-hand knowledge for proceeding effectively with managing their waste. This approach limits unnecessary government intervention and duplication. Therefore, in its response to the report [from the EARP Panel], the Government of Canada made clear that it expected that waste producers and owners to establish, organise and manage a Waste Management Organisation, as a separate legal entity, over which the Government will exercise appropriate federal oversight.



Schematic drawing of possible geologic disposal facility for nuclear fuel waste.

The Waste Management Organisation

The Government of Canada expects that:

- The producers and owners of nuclear fuel waste in Canada will establish a Waste Management Organisation, incorporated as a separate legal entity, with a mandate to manage and coordinate the full range of activities relating to the long-term management, including disposal, of nuclear fuel waste. The major producers and owners are in the best position to proceed effectively with waste management operations. The Waste Management Organisation would:
  - → have a Board of Directors, with fair representation of producers and owners of nuclear fuel waste;
  - → have an advisory council, possibly including representative from the public, academia, workers, international experts, environmental and other non-governmental organisations as appropriate; and,
  - → be comprehensive, i.e., allow for the participation of all producers and owners of nuclear fuel waste. The Waste Management Organisation would have to consider not only all existing waste producers and owners but the possibility of future producers as well.

- The Government also expects that the producers and owners of nuclear fuel waste will establish a segregated and dedicated Fund to finance fully all activities of the Waste Management Organisation, including the cost for the long-term management, including disposal, of nuclear fuel waste.
- The Waste Management Organisation will report back to the Government of Canada setting out its preferred overall approach for long-term management, including disposal, of nuclear fuel waste, with justification and including:
  - → a comprehensive public participation plan, particularly for members around potential siting areas;
  - → a framework to assess ethical and social considerations, such as potential impacts on future generations, impacts on socio-economic life of the community;
  - → an Aboriginal environmental participation process to ensure fair participation by Canada's Aboriginal peoples, which takes into account their particular needs, concerns and lifestyle;
  - → practicable long-term waste management options for Canada, including the following: a modified concept for deep geological disposal, for example including the retrievability option; storage at reactor sites; and centralized storage, either above or below ground;
  - → a comparison of risks, costs and benefits of the options from, e.g., a health, environmental, economic, social, and security/safeguards perspective; these options would need to be analysed within the context of proposed siting areas; and,
  - → future steps; it is expected that the Waste Management Organisation will make recommendations for proceeding after the Government of Canada decision on its preferred management option, including disposal, and where the facility could be built. The Government of Canada will then decide if it accepts the Waste Management Organisation's report and consider its preferred approach for disposal.

The Government chose to maintain the responsibility of long-term management of nuclear fuel waste close to the producers and owners of the waste. However, with this approach, there is clearly a need for credible federal oversight.

Federal Oversight

For a project of such a magnitude, it not sufficient for the Government, through its nuclear regulator, to control only the health, safety, security and protection of the environment aspects of the disposal of nuclear fuel waste. The impact of the project goes much further and the Government of Canada wants to ensure that the wastes will be taken care of in a comprehensive, cost-effective and integrated manner. Federal oversight is needed to ensure that the project is consistent with all relevant Government of Canada policies, including sustainable development considerations.

The Government of Canada identified three key policy objectives of a proposed federal oversight mechanism:

- to establish a dedicated Fund to be paid by the producers and owners of nuclear fuel waste for financing fully the long-term management, including the disposal, of nuclear fuel waste;
- to establish a reporting relationship between the federal government and the Waste Management Organisation, for reviewing progress on a regular basis; and
- to establish a federal review and approval process to exercise federal oversight and to provide access to the dedicated Fund for operational activities leading to the ultimate disposal of the waste.

Following the public release of the December 1998 Government Response, Natural Resources Canada officials consulted with federal departments, the AECB, waste producers and owners, the provinces, and the public to determine if other options would be as effective as legislation.

Given that Canada is at a key stage in the development of an approach to nuclear fuel waste management, much emphasis was put on consultations with the public. The Government Response was posted on the internet on December 3, 1998. Copies of the Government Response were sent out to individuals, interest groups, and public libraries. Public consultations were held in various cities across Canada. Public consultations finished on February 28, 1999. These consultations highlighted and confirmed that one, and likely the best, means of ensuring that policy objectives of the Government are met, would be through the development of federal legislation. Other options suggested for further consideration include:

- legal mechanisms such as contractual agreements, memoranda of understanding or agreement; and,
- voluntary mechanisms such as verbal agreements or inclusion of federal requirements into corporate by-laws.

In addition, a separate consultative process for Aboriginal Groups was initiated. In this regard, the Minister of Natural Resources Canada contacted the Assembly of First Nations, the Inuit Tapirisat of Canada, the Metis National Council, the Congress of Aboriginal People, and the native Women's Association of Canada.

The major stakeholders are the three nuclear provinces and their utilities. There was a general understanding of the federal government's reasoning for oversight. There was also general support for the principle of depositing moneys into a segregated Fund as this would demonstrate governments' commitment to ensuring that financial resources will be available over the long-term. Nevertheless, each province has its own specific concerns and discussions are on-going with each of the provinces in order that their concerns be addressed.

Recommendations will be submitted to the Minister of Natural Resources in the near future. The Minister will present these to his Cabinet colleagues for decision on the next policy steps for the long-term management, including disposal, of nuclear fuel waste. Such a decision is expected in late 1999.

Conclusion

The Government of Canada needs to maintain the existing momentum and continues to move towards a permanent solution for the long-term management of nuclear fuel waste. There are several reasons why it is important to move ahead, albeit carefully, democratically, and in a step-wise manner.

- On-site storage of nuclear fuel waste at nuclear generating stations is safe. However, a long-term solution will eventually be required, such as disposal in a deep repository. The siting and construction of such a facility can take some time and it is prudent to begin the process as soon as practicable. This view was also expressed by the UK Lords in their recent report (UK House of Lords, 1998) on the disposal of radioactive waste. They placed much emphasis on the urgency of the problem: "Overall, from the standpoint of immediate safety, the present situation is under control, however the size of the task ahead and the time-scale of any foreseeable solution make a political decision on future strategy a matter of urgency";
- The Government of Canada, in taking a stance, will increase public confidence that neither current nor future generations will be negatively impacted by nuclear fuel waste, and that its approach to the long-term management, including the disposal, of nuclear fuel waste is consistent with sustainable development principles;
- The present generation benefited from nuclear energy, and produced the resulting wastes; it therefore should be responsible for their long-term management, including disposal. This does not preclude future generations being involved in final decision-making processes since a step-wise phased management approach would allow them to make directional changes. The will to move ahead demonstrates the Government's commitment to deal effectively with the long-term management of nuclear fuel waste by not leaving this task up to future generations;
- It is good waste management practice and good business sense to define long-term waste management practices as early as possible (e.g., waste treatment for storage should ideally be consistent with eventual disposal activities to minimize the risks and costs of any waste reconditioning);

The Government has clearly stated that it has not yet made a decision on its preferred concept for the long-term management, including disposal, of nuclear fuel waste. A step-wise approach has been adopted allowing for a reasoned development of the most effective solution for the long-term management, including disposal, of nuclear fuel waste in Canada. In this way, the Government will move ahead; a "wait-and-see" approach is no longer tenable since it might lead to a time when storage is no longer considered safe and yet no permanent solution has been developed due to unwarranted delays.

Managing Canada's nuclear fuel waste is a significantly large project which will involve billions of dollars and take place over 70 to 100 years. The Government of Canada will assume its federal oversight responsibilities and expects the cooperation of the waste producers and owners. Such cooperation will lead to effective nuclear fuel waste management activities which will be in the best interest of both present and future generations of Canadians.

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3rd International Conference on Isotopes

With a majority of the 250 or so delegates coming from outside Canada, the **3rd International Conference on Isotopes,** held in Vancouver, September 6 - 10 , 1999, was truly an "international" conference.

This series of conferences began with a conference in Beijing, China in 1995. The idea was picked up by the Australians with a second conference in 1997 in Sydney. This third conference was hosted by the Canadian Chapter of the International Isotope Society and organized primarily by people àt TRIUMF. As with most Canadian conferences this one was very well organized and operated and, with good weather, the attractive Vancouver setting appealed to all..

Helen Garnett

The theme of the four-day conference was: ***Isotope Production and Applications in the 21st Century*** and focussed on three main fields of isotope application : in medicine, industry, and the environment.

Over 100 papers were presented orally and another 50 in poster sessions. The range of topics can be judged by the titles of the sessions:

- Isotope Facilities and Programs
- Radiochemical Synthesis
- Nuclear Analytical Applications
- Radioisotope Production
- separation and Applications of Stable Isotopes
- Industrial Applications and Radiation Safety
- Radiopharmaceutical Applications and Medical Imaging
- Production and Application of Isotope Tracers in Industry
- Use of Isotopes in environmental Studies
- Applications of Isotopes in Medical Imaging and Therapy
- Radiation Safety Aspects at Isotope Facilities
- Applications in Agriculture and Nutrition
- AMS and Radiocarbon Dating Techniques
- Production and applications of Short-Lived Radioisotopes
- Labeling compounds and Other Application of Tritium
- Novel Applications of Isotopes and Opportunities for Technology transfer.

In the opening paper of the conference, Dr. Alan Astbury, TRIUMF director, provided an overview of the work at the centre. He noted that their five-year funding arrangement from the federal government ends this year. They are seeking $43 million per year, $10 million more than in the current agreement.

Another plenary presentation, the talk by Prof Helen Garnett, associate director of the Australian Nuclear Science and Technology Organization (ANSTO), was very interesting, especially for those concerned about the fate of the proposed Canadian Neutron Facility (CNF). She mentioned a long period of "lobbying" politicians and government officials for a new research reactor at the Lucas Heights Science and Technology Centre and emphasized the need to communicate to them the value of the facility in terms they could appreciate. The project completed a 1-year EIS (environment impact assessment) process in April 1999. Final government approval is expected this fall with construction to begin in 2000.

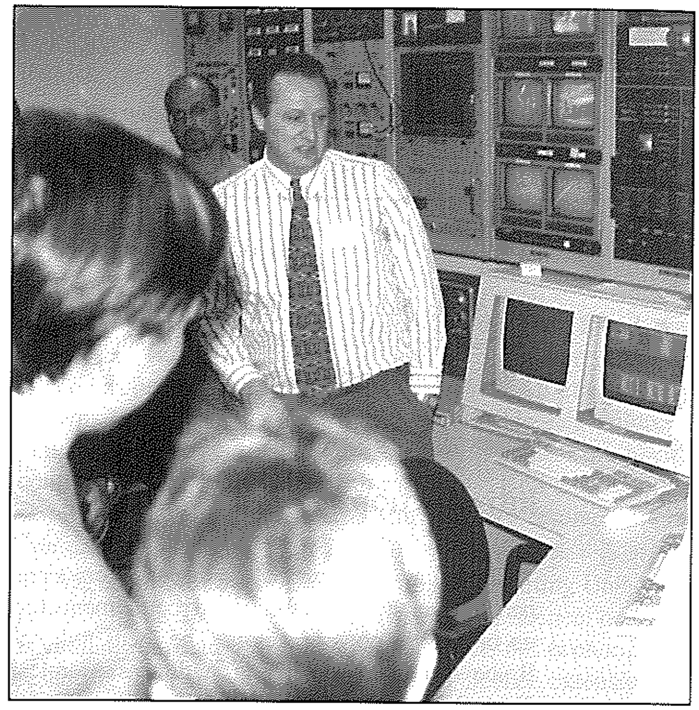
Other overview papers in the opening plenary sessions were presented by speakers from the International Atomic Energy Agency, Russia, and China along with Canadian papers on the new MAPLE isotope production reactors at Chalk River and the ISAC facility at TRIUMF.

On the afternoon of the second day delegates were bussed to TRIUMF which is located on the grounds of the University of British Columbia. There they were given tours and explanations of the many experimental and production facilities associated with the world's largest cyclotron which is the heart of TRIUMF. *(The name, incidently, was coined three decades ago at the inception of the project as an abbreviation of "Tri University Meson Facility" after the original three university partners: University of British Columbia, Simon Fraser University and University of Alberta. Today, the University of Victoria has become a member of the joint venture and six other universities are associate member: Carleton, Manitoba, Montréal, Queen's, Regina, Toronto.)*

Beams from the main cyclotron are directed into four facilities: the proton hall; the meson hall; MDS Nordion's production facility; and the newest addition the Isotope Separation and Acceleration (ISAC) facility which produced its first ion beam with short-lived exotic isotopes on November 30, 1998. MDS Nordion has two small cyclotrons in its facility for the production of specific isotopes.

Among the many uses of TRIUMF is the treatment of cancer, specifically ocular melanoma, with a proton beam. Another development was the design and construction of one of the four original PET (positron emission tomograph) scanners in Canada. Other applications of research conducted at TRIUMF include: the development of a detector to detect plastic explosives or some types of illicit drugs using imaging technology; creation of computer micro chips that can store information rapidly in the right sequence; and improved understanding of superconducting materials. TRIUMF will celebrate the 25th anniversary of its first beam with a one-day symposium December 13, 1999, in conjunction with a meeting of the TRIUMF Users' Group.

A "handbook" containing abstracts of all of the papers was provided at the conference. Copies could be obtained from the conference chairman, Dr. Nigel Stevenson, TRIUMF, Vancouver, B.C. , e-mail: < nigel@triumf.ca >.



Nigel Stevenson, conference chairman, explains a control room at TRIUMF to visitors from the 3rd International Conference on Isotopes, Vancouver, September 1999.

Quotable quotes

by ***Ron Osborne,*** *President and CEO, Ontario Power Generation Inc.. to a meeting of the world Association of Nuclear Operators (WANO) in Victoria, B.C. September 29, 1999.*

" There is one over-arching objective that remains critical for the nuclear industry in Canada. That goal is to renew the spirit of partnership and collaboration between the federal government, provincial government and the nuclear industry. I say "renew" because the nuclear industry in this country grew out of a proactive, overt partnership between the industry and governments.

As Ontario moves into a competitive market, I think it will be a unique opportunity for all interested parties to work cooperatively so that our country continues to benefit from the advantages of nuclear power. It is only through this cooperation that we can create the context in which we can attract private equity and reduce dependence on government sponsorship."

by ***Dr. Agnes Bishop,*** *President, Atomic Energy Control Board, to a special meeting on nuclear regulatory effectiveness, held by the Nuclear energy Agency of the OECD in June 1999.*

"It is often difficult to attribute industry performance to the actions of the regulator. Is the industry doing well because of the regulator, or despite the regulator ?Is a particular licensee performing well because it is a good operator, or because it is well regulated ?"

"We have noted a distinct lack of interest among young people in the whole are of nuclear technology. What effect will this have on our regulatory effectiveness 10 or 20 years down the road? How can the regulator attract and retain competent staff?"

by ***Mohamed ElBaradei,*** *Director General of the International Atomic Energy Agency, to the IAEA General conference, September 1999.*

"The assumption that environmental considerations alone will trigger a resurgence of investment in nuclear power generation is at best doubtful. Only if the nuclear power industry consistently reflects three crucial attributes - safety, competitiveness, and public support - can it be assured of a long-term future."

"The key to an effective safety regime is the full application of conventions and standards at the workplace, with particular attention paid to managerial and organizational practices."

Lay-Up of Power Reactors:

-Regulatory Considerations

by: P.G. Hawley[1]

Ed. Note: this paper was first presented at the 20th Annual conference of the Canadian Nuclear Society in Montreal, June 1999.

Introduction

The intent of this paper is to discuss, from a regulatory perspective, the acceptability and requirements for the lay up of nuclear power reactors. The focus will be on the Bruce A nuclear generating station as Atomic Energy Control Board (AECB) staff prepare to make a recommendation on the operating licence in the year 2000. This paper does not discuss Bruce A restart issues.

In Canada, nuclear facilities are regulated by the AECB, an agency of the Federal Government. Its mission is to ensure that the use of nuclear energy in Canada does not pose undue risk to health, safety, security and the environment.

In the province of Ontario there are twenty CANDU power reactors owned by the electrical utility, Ontario Power Generation Inc. (formally Ontario Hydro). They are located at three different sites: four 900 MWe reactors at Darlington, eight 500 MWe at Pickering and eight 800 MWe at Bruce. At Pickering and Bruce, the units are in two sets of four, designated Pickering A, Pickering B and Bruce A, Bruce B. The reactors range in age from about five years to twenty-five years of service.

Ontario Power Generation has struggled to turn recent poor performance around with a myriad of organizational and program changes. In December of 1996, Ontario Hydro's then Chief Executive Officer, Dr. Allan Kupcis hired Mr. G. Carl Andognini as Executive Vice President and Chief Nuclear Officer. Dr. Kupcis immediately directed Mr. Andognini to conduct the type of "brutally honest" assessment of Ontario Hydro Nuclear conducted by the American nuclear industry. In January, 1997, Mr. Andognini chartered the Nuclear Performance Advisory Group to perform and Independent, Integrated Performance Assessment (IIPA) of Ontario Hydro Nuclear. The IIPA team ranked all of the operating stations as minimally acceptable. This rank was stated to be consistent with the lower ranks that the Institute of Nuclear Power Operators (INPO) would issue and still permit the plants to operate if in the USA. It also was also stated that it indicates that immediate attention is required to improve performance or even maintain current performance.

In response to the IIPA, Ontario Hydro produced the Nuclear Asset Optimization Plan (NAOP). NAOP is a major recovery plan designed to implement the recommendations in the IIPA. It calls for a phased recovery of the performance of Darlington, Pickering B and Bruce B over an initial four year period and Pickering A followed by Bruce A over the subsequent years. The "A" units would be laid up in order to allow release of resources to improve the performance of the newer stations. Restart of the "A" units would be conditional on an approved business case on a unit by unit basis. Discussions between Ontario Power Generation and AECB staff regarding restarting the first Pickering A unit next year have already begun. Before Bruce A is restarted, it would have to undergo some major rehabilitation which would include new boilers and pressure tubes.

What is Lay Up?

It is important to understand exactly what is meant by "lay up" because a rigorous definition of the term will help determine its requirements. Lay up is the **time limited shutdown,** and preservation, of a nuclear facility in conjunction with the **suspension** of the activities/issues associated with that facility.

In Canada, we have had experience with extended outages (i.e. years) required for the replacement of pressure tubes however there is a fundamental difference between a lay up and an extended maintenance outage. The objective of the lay up is to reduce expenditures and activities in order to reduce or free-up resources. Staff is reduced, as many systems as possible are taken out of service, and costs are minimized. This is in contrast to a maintenance shutdown (or presumably decommissioning) where activity and resource expenditure remains high. Staffing, for example, during a maintenance outage will often increase.

1 Patrick Hawley is currently Head, NAOP - IIP Review, at the Atomic Energy Control Board in Ottawa. At the time of writing he was AECB Project Officer at Bruce A NGS.

Other Regulatory Agency Positions on Reactor Lay Up

Some other regulatory agencies were contacted to learn about their experience and position with respect to lay up. Those contacted were: the International Atomic Energy Agency (IAEA), the Swedish Nuclear Power Inspectorate (SKI), the UK Nuclear Installations Inspectorate (NII), the Swiss Federal Nuclear Safety Inspectorate (HSK) and the US Nuclear Regulatory Commission (NRC).

None of those contacted had any sort of formal recognition of a state of lay up. States that are recognized are construction, operating and decommissioning.

IAEA Project A.2.05 currently underway on Management of Delayed Nuclear Power Projects is meant for projects delayed during construction however it covers some of the same issue faced for lay up. These include human factors, maintenance requirements, upgrade requirements etc. At the time of writing the project has produced two working documents: one on the preservation and maintenance of site installations, structures and equipment and one on the retention of human resources and preservation of construction data.

NUREG/CR-6451, "A Safety and Regulatory Assessment of Generic BWR and PWR Permanently Shutdown Nuclear Power Plants" provides a rational for licence exemptions based on the status of the fuel. That is, more exemptions are allowed as the fuel is moved from the reactor, cools in storage on site and finally, is move off site. The approach seems reasonable.

Also available from the US are many guides with respect to the management of shutdowns. NRC Inspection Manual Chapter (IMC) 0350, "Staff Guidelines For Restart Approval" could be very useful for regulatory site inspection staff in assessing licensee readiness to restart.

Finally, the Electric Power Research Institute (EPRI) has published EPRI NP-5106: "Sourcebook for Plant Lay Up and Equipment Preservation".

Browns Ferry Unit 1

In terms of actual lay-up experience, the best found was Tennessee Valley Authorities' (TVA) Browns Ferry Unit 1 which has been shut down since March, 1985. All three units at Browns Ferry were shut down at that time due to a failure to maintain a documented design basis and to control the plant's configuration in accordance with that basis. Unit 2 returned to service in May 1991 and Unit 3 subsequently resumed operation in early 1996.

TVA continues to preserve the option of restarting Unit 1 and is retaining its operating licence. Time on the licence, however, is running out and with only 14 years left, the economics of restarting the unit without some kind of licence extension are becoming poor. The position of the US Nuclear Regultory Commission (USNRC) is that as long as TVA continues to meet regulatory requirements, the unit can remain licenced as an operating unit. The USNRC's Technical Specifications are broad enough to allow suspension of testing etc. while a unit is shut down.

In April, 1998 the Union of Concerned Scientists submitted a petition to the NRC pursuant to 10 CFR 2.206 requesting that the operating licence for Browns Ferry Unit 1 be revoked. The

Bruce nuclear power development with Bruce 'A' in foreground.

issues raised in the petition bear scrutiny and will perhaps become more compelling for Bruce A as time goes on. The main thrust of their argument is summarized in the following points:

- For Browns Ferry Unit 1, TVA has not addressed any of the approximately 39 bulletins, 141 generic letters and 1,047 information notices issued by the NRC to its licensees during the time Unit 1 has been shut down. TVA's response has been that these will be taken into account prior to returning the unit to service.
- The material condition and configuration management problems can only have gotten worse since the unit was shut down for these very reasons.
- It is unlikely that the plant will be restarted. No US commercial nuclear power plant has ever returned to service after an outage lasting over 12 years.
- Granting the petition would move Browns Ferry Unit 1 out of "administrative hold", a non-defined regulatory state, into a condition governed by applicable regulations [i.e. those for decommissioning].
- If TVA elects to restart the unit, the regulatory process for granting a new licence would be better and safer in this case rather than following the administrative process for restarting a problem plant.

The NRC concluded that "the petition raised novel issues with respect to maintaining an operating license for a facility for which there are no plans for future operation..." and they accepted the petitioner request for a public hearing. The hearing was held on October 26, 1998 at Browns Ferry.

On March 29, 1999 the NRC Director's Decision concerning the petition was published. It is available at the US Federal Register Internet site (www.nara.gov/fedreg.). The Petitioner's requests for the NRC to revoke the Browns Ferry Unit 1 operating licence and to require TVA to submit a decommissioning plan or a lay-up plan for Unit 1, and for the NRC to conduct inspections against the decommissioning plan were denied. Part of the reason for the denial, was the demonstrated success of NRC experience using the above mentioned NRC IMC 0350. There was no "demonstrated basis for the assertion that facility restart based upon IMC 0350 is a less reliable process for resolving the safety concerns of a problem plant than the relicensing process". The decision will now undergo review by the Commission.

AECB Staff Position

It is AECB staff position that lay up:

- should not be used or cause an unwarranted delay or avoidance of decommissioning;
- should not be a form of abandonment; and,
- should not be used to prolong the operational period of a design that would not otherwise meet new requirements.

There must be a reasonable probability that the unit will be restarted.

As a minimum, the following should be (and were) provided to the AECB when a decision has been made to lay up one or more reactors:

- a statement of intent to lay up
- the reason for the lay up
- the planned time period for the lay up
- a commitment to continued safety and security

This will allow for an assessment of the reasonableness of the request to determine that it does not fall into one of the negative categories mentioned above.

It is an interesting exercise to review the steps in the initial licensing process to see how far back in the process the facility is placed by lay up. In Canada, the major steps to achieving an operating licence are:

- Letter of Application Sent
- Submission of Final Safety Report
- Submission of Commissioning Programs
- Submission of OP&Ps, Radiation Protection and Emergency Procedures
- Safeguards and Security in place
- Submission of Construction Completion Assurances
- Authorization of Staff
- Approval to Load Heavy Water and Fuel
- Provisional Licence Granted (for start up and post criticality testing)
- Operating Licence Granted

At Bruce A, the reactors have been officially defuelled since October 1, 1998. Second, and perhaps the most important, backwards step on the list is the loss of authorized staff. AECB authorizing of staff lasts "...as long as they are employed as such..." and with time no Bruce A staff will be able to claim that they are continuing the role for which they were authorized. Ontario Hydro can mitigate against many of the other items in the list by doing a good job of maintaining the systems and configuration control. If it choses not to do this, then one can see that over time we would slide back to the start of the operating licence process. Thus the likely-hood that AECB staff would make continued positive recommendations for licence renewal for a laid up station is small. The AECB does not have the equivalent of the NRC IMC 0350 so redoing the process for obtaining the original operating licence may be most appropriate. Whatever process is used, the public will be given the opportunity to express their views and/or appear before the Board.

Current Status of the Licence

In Canada, the operating licences for power reactors are renewed on a periodic basis, typically every two years. The operating licence for Bruce A expired on August 31, 1998. Ontario Hydro applied for a two year renewal.

As part of the licence renewal process, interested groups or members of the public can make submissions expressing their views to the Atomic Energy Control Board. Some questioned whether an operating licence would be appropriate for a station that would not be operated at power during the licence period. AECB staff considered this also. In making the recommendation to the Board that an operating licence was appropriate the Board staff considered the following:

- There would still be fuel left in one or two of the reactors at the time the licence expired. Therefore they would still have to be operated and maintained to control reactivity and provide cooling, i.e. the fundamental safety objectives of operation would still be present.
- If the units are to be restarted in future, they will have to be maintained in the interim. Such maintenance can be viewed as a mode of operation of the facility.
- Ontario Power Generation (OPG) stated that a decision to restart Bruce A units is scheduled to be made prior to the end of 1999. A licence period to the end of August 2000 will allow time for the AECB to consider the results of this decision, whichever direction it takes.

Another point that was expressed in submissions to the Board was that OPG be required to establish a fund for the decommissioning of Bruce A reactors. The Nuclear Safety and Control Act (which is now scheduled to come into effect in early 2000) will allow financial guarantees to be one of the conditions of the licence and this may well be pursued.

At the August 13, 1998 Board meeting, the Board renewed the Bruce A operating licence for a period of two years. A new condition of the operating licence states that all the units will remain in an approved shutdown state. Note also that not all of the justification presented above for a renewed operating licence would apply to a further renewal.

Licence Exemptions

The shutdown and defuelling of the reactors allowed for exemptions to the licence. The most common of these was a series of revisions to the Station Policy on required staff complement. Approval at AECB Director level was necessary for each revision. The new (current) licence incorporates requirements for staffing up to and including the completely defuelled state. The key points from Section A.A.3 iii) of the current licence are:

when any reactor unit contains fuel:

- there shall be in the nuclear facility at all times at least one Authorized Nuclear Operator for each reactor unit containing fuel, one Unit 0 Supervising Nuclear Operator and two Shift Supervisors, one of whom may be a Shift Operating Supervisor
- there shall be in the station main control room at all times a minimum of one Major Panel Operator qualified to operate the Unit 0 control room panels, and either two Authorized Nuclear Operators when three or four reactor units contain fuel, or one Authorized Nuclear Operator when only one or two reactor units contain fuel.

When all reactor units are in a guaranteed defuelled state:

- there shall be in the nuclear facility at all times, at least one Authorized Nuclear Operator, one Supervising Nuclear Operator and one Shift Supervisor
- there shall be in the station main control room at all times a minimum of one Operator qualified to operate the reactor panels and the Unit 0 control room panels.

After all the units were defuelled, Ontario Hydro requested approval to allow a Shift Operation Supervisor to act in the place of the Shift Supervisor. We agreed to this request with constraints that requirements of the OP&Ps still be met, e.g. that jumpers receive Shift Supervisor approval. Thus far, Ontario Hydro has retained Shift Supervisors on shift but that may change soon.

Also as the units were shut down and defuelled, testing and maintenance requirements changed. Many tests no longer made any sense on a defuelled reactor. This was dealt with by a new revision to the Operating Policies and Principles (OP&Ps) (Revision 13) which formally recognize the Defuelled Guaranteed Shutdown State (DGSS.). Several sections in Revision 13 of the Bruce A OP&Ps end with a statement that "these policies do not apply to reactor units in the defuelled guaranteed shutdown state". Example sections include those on:

- the control of core reactivity
- moderator level and purification requirements
- alternate heat sinks requirements and heat transport inventory monitoring
- special safety system and reactor regulating system maintenance requirements
- boiler safety valve capacity and testing requirements
- trip set points
- absorber operation

Ontario Hydro was also granted relief on requirements of the Periodic Inspection Program and leakage testing of the negative pressure containment system.

The Operating Licence also makes requirements for reporting in accordance with Regulatory Document R-99, "Reporting Requirements for Operating Nuclear Power Facilities". Ontario Power Generation may seek exemptions from parts of this, for example, the requirements to produce an annual Reliability Report and Quarterly Technical Reports.

Outstanding Commitments to the AECB

After the decision was made to lay up Bruce A, Ontario Hydro conducted a review of outstanding commitments made to the AECB. A total of 278 commitments were divided into three categories: those which could be closed, those which would be continued and those which would be suspended. The rational for placing a commitment in a particular category was provided by Ontario Hydro. AECB staff then reviewed the resulting data base and was in agreement with all but a few of the categorizations.

Commitments which could be closed had all actions complete and required nothing more than an agreement to close. Continued items are typically those which were far along the path to resolution or were ongoing commitments to follow certain procedures still necessary at the time of the review. Suspended commitments were those for which all work was stopped.

The careful recording and storing of suspended commitments is an important process for a licensee that wants to restart reactors in future. Such commitments will have to be revived and, in fact, resolution of some will be a prerequisite to restart. Thus it is important to document not just a description and current status of the commitment, but also the anticipated effort required to complete and the appropriate trigger for its reactivation. The suspended Bruce A Risk Assessment, for example, is an important commitment which will require much lead time and should be revived immediately after a decision to refurbish and restart the units.

The fields in Ontario Hydro's regulatory commitment database include:

Reference Number
Title
Description of Issue
Current Commitment/Deliverable
Recommendation [to continue, close or suspend]
Basis for Recommendation

and in the case of suspended items, there are the additional fields:

Re-start Milestone
Lead Time for Completion

Ongoing Requirements

There are ongoing radiation protection requirements. A major decontamination program is not required but we would expect that the number of rubber areas would be diminished. Fixed area monitors need to remain in service and routine surveys completed. While containment may not be necessary, it is probably prudent to maintain airlocks so that "containment" is at least "confinement".

The licensee must also be diligent about configuration management. The lay up process would likely involve the physical removal and storage of equipment. Licensees such as Ontario Hydro with more than one station may be tempted to use this equipment at other locations. AECB staff accept that this can be managed with an established temporary change control process but it must not be allowed to degrade.

To their credit, Ontario Hydro is being strict on the use of parts from Bruce A. To do so requires the approval of the Site Vice President and to date, only two items of USI equipment have been take to Bruce B: Unit 3 pressurizer heater 6 and emergency core injection heat exchanger plates. Also, there is a policy of ordering replacements for any parts taken.

Emergency plans must remain in effect to address the limited number of still credible emergencies at the station. The most important of these are fires and tritiated water spills. Degassing of the generators should be a high priority to remove one of the larger fire hazard.

Compliance with the Physical Security Regulations and fulfilling obligations to the International Atomic Energy Agency with respect to safeguards remain a requirement.

AECB Monitoring

AECB staff will continue to monitor Bruce A as part of its compliance verification function. For the 1999 fiscal year, there were 69 Project Officer days scheduled for Bruce A compliance verification (about half of that scheduled for Bruce B). This information will be an input to the recommendation on Bruce A licence renewal the following summer.

There are five types of compliance activities comprising the verification program:

1) Field Inspections:inspections of selected areas within the station. Over the course of the year, most areas will have been inspected
2) Operating Practice Evaluations:evaluations of specific activities such as a start-up. None of these have been scheduled for Bruce A.
3) System Inspections: inspections of specific systems. Six systems are scheduled:
   Liquid Effluent Monitors
   Fixed Gaseous effluent Monitors
   Primary Spent Fuel Bay
   Freezing Protection System
   Humidity Control
   Low Pressure Service Water
4) Observations: Observations of emergency drills: Will be done ad-hoc as they occur.
5) Audits: Two planned, one on Security and one on Operating Experience.

During our field inspections, we expect to find that housekeeping will be maintained to minimize the possibility of contamination spread and fire hazards. We expect leaks to be fixed. We expect radiation hazard signs to be filled in and up to date.

The systems chosen for inspection are those that are still required to operate during the lay-up. Later, the emphasis will switch to system condition with respect to the impact of being laid up. Signs of equipment degradation will be recorded as possible impediments to restart.

Summary

Lay up has been defined as the time limited shutdown and preservation of a facility in conjunction with the suspension of activity associated with that facility. It is an approach being used by OPG to free resources which can then be applied to improve performance at other locations. The lay up state has not been formally recognized in the world community. It is our view that lay up is acceptable from a regulatory perspective if the time period is defined and reasonable, there is a commitment to continued safety and security, and it is apparent that the restart of the reactors remains viable.

In August of 1998, the AECB accepted that an operating licence was appropriate for the following two years of Bruce A operation. AECB staff will consider the issues discussed in this paper in making a recommendation one way or the other for licence renewal in the summer of 2000.

A commentary

Fusion Research's Demise in Canada "another Avro Arrow"?

by Richard Bolton[1]

Ed. Note: *Although the following treatise was presented at the 20th Annual Conference of the Canadian Nuclear Society in Montreal, June 1999, it is much more of a comment than a technical paper. Nevertheless, we also deplore the actions of our government in cancelling the fusion program and feel that the sentiments expressed are very important.*

The difficulty in writing this presentation was not in the factual content but was in finding the proper tone. One has to think through what one wants to accomplish - is it to set the record straight, to explain why, to lay blame, to embarrass or to try to mitigate the effects? I have vacillated back and forth between all these [while preparing this presentation].

Let me get directly to the topic.

In 1997, the Canadian Government officially and unilaterally ended the highly successful National Fusion Program that it had cost-shared with Hydro-Qubec and Ontario Hydro for the previous 18 years. This program was originally started by NRC and then transferred to AECL around 1984. The National Fusion Program had a program office within Atomic Energy of Canada Limited (AECL) at Chalk River and two research centres, the Centre canadien de fusion magntique (CCFM) in Varennes, Qubec and the Canadian Fusion Fuels Technology Project (CFFTP) in Mississauga Ontario. The CCFM budget was shared with Hydro-Qubec and INRS and CFFTP's costs were shared with Ontario Hydro and the Government of Ontario.

Both these centres were relatively young in the international context of fusion research and both had modest budgets in comparison with those of the major players abroad. Nevertheless, they had made their names for the quality of the research work and in particular for the impact per dollar spent. Canada?s total annual spending on fusion research at that time was in the range of 25 million dollars, compared to the total world annual spending of between two and three billion dollars. These 25 million dollars were sufficient to make a significant contribution to fusion research, and more importantly this contribution was very well recognized by the other players.

CCFM and CFFTP were able to make their names internationally, in spite of their youth and limited resources, by having highly focussed programs in niche areas of fusion research that had been tailored to match existing Canadian knowledge and industrial capabilities. I will not discuss the technical content of the programs here, but it should be noted that the Tokamak de Varennes experiment at CCFM, was in its prime in 1997. Many years of pertinent and significant experiments were arrested prematurely by its closure just after a major costly upgrade to its performance.

The world program of fusion research is continuing vigorously and heading toward the construction of the International Thermonuclear Experimental Reactor (ITER). In spite of a recent US decision not to participate in ITER, of which they were a founding partner, Europe, Japan, and Russia are still pursuing ITER vigorously, albeit with a modified mandate and reduced scale. The US has, however, recently started construction of the National Ignition Facility, a multi billion dollar research facility for laser (or inertial) fusion.

As an illustration of the technical progress of fusion research, it is well documented that over the last few decades, the rate of increase in fusion parameters obtained has exceeded that of semiconductor memory chips, considered the prime example of rapid technological advance.

The four major players of fusion research in the world are shown in Figure 1 with some brief indications of their activities.

Figure 1.

World Fusion Players

First tier

Japan
2 G$ Toroidal Magnetic Facilities
Europe
JET G$ tokamak + many other large expts.
US
Large tokamak + NIF G$s laser being built
Russia
Older experiments and considerable capability

1 Dr. Bolton, a Fellow of the Canadian Nuclear Society, is the former director of Centre canadien de fusion magntique. He now has his own consulting company in Montreal.

Figure 2 shows the situation at the next tier as it was in 1996. Canada had one of the most significant programs after the first tier.

Figure 2.

World Fusion Players

Next tier - Before

Canada
China, South Korea, India
All with large new pojects
Australia, Brazil, Mexico, Iran, Ukraine . .
Lower level activities
Paraguay, Kenya, . . .
No known activities

As a result of the termination of the National Fusion Program, Canada is now the only G-7 country without significant experimental research in fusion energy. In fact, as shown in Figure 3 it now ranks below many countries with much smaller economies, and, much more significantly, countries with very much lower pretensions in the area of high technology development.

Figure 3.

World Fusion Players

Next tier - After

China, South Korea, India
All with large new pojects
Australia, Brazil, Mexico, Iran, Ukraine . .
Lower level activities
Paraguay, Kenya, . . .
No known activities

The research programs at CCFM and CFFTP have already been dismantled and the experimental installations of the CCFM, the tokamak and all of its subsystems, are in the process of being crated for shipment abroad. Serious expressions of interest have been received from both highly developed countries and developing ones.

*(**Ed. Note:** Readers may recall the reported proposal in the summer of 1999 to sell the equipment to Iran which was quickly squashed when it became public knowledge.)*

What are some of the direct consequences of this decision?

Here I will concentrate my remarks on the case of CCFM, but analogous consequences obtain in the case of CFFTP.

In the first instance, by Cabinet fiat, a whole branch of science, i.e., that of experimental high temperature plasma physics has been wiped out in Canada. This is an unprecedented situation. In comparison to other G-7 countries, this field was already grossly under represented in Canada, perhaps by a factor of four. When disaster struck the 30 PhD's at CCFM, almost all the jobs in the country disappeared. Those in mid-career are hit particularly hard. They must start a new scientific career; a process normally taking years. In contrast, in the case of the cancellation of TASCC, (the super conducting accelerator at Chalk River) the percentage effect on jobs in experimental nuclear physics in the country was clearly smaller, there being several major experimental facilities in the country and even some new ones in the planning stages. The effect on the other 70 engineering, technical and support staff at CCFM is less severe because of the greater versatility and the shorter time required to reintegrate them.

I would like to be able to say that the professional associations involved screamed blue murder about this, but such is not the case. From my perspective, the Canadian Nuclear Association (CNA) was dominated at that time by AECL which was directly involved in the cancellation as we shall discuss later. The Canadian Association of Physicists (CAP), which is heavily weighted toward nuclear and solid state physics, did add us to their protest about the closing of TASCC, SAL, and the neutron scattering program, but except for the president of the CAP at the time, their heart did not seem to be in it. In the end, they lost a whole division.

The decision to terminate this program will have important strategic consequences for the Country. This new technology is being vigorously developed elsewhere, and it will come into being without Canada?s input. In particular, Canada?s technology will not be part of the base and our manufacturers will not be part of the development process. Not only will the main technology be imported for use here, but most of the supporting technology will be as well. This last is particularly important because Canadian industry will miss out on many opportunities to sell its wares abroad in the niche areas that were being developed as part of the National Fusion Program strategy.

When we buy fusion reactors, we will probably be in the sad, and even humiliating, position of begging for technological transfer inward toward Canada in a field in which we used to have valuable and saleable expertise. This will be the complete reverse of the current situation in the fission industry where Canada's clients are requesting technology transfer outward to them!

With respect to the number of jobs lost, in the 100 to 200 range, the immediate effect of the cancellation of this program is not nearly as dramatic as the cancellation of the Avro-Arrow was in its time. Nevertheless, the long-term implications are of similar order. In its simplest terms, it has now been decreed that Canada will be a buyer of this technology, and not even a seller of technical subsystems toward which the program aimed. The relative constancy of the markets for combat aircraft and power stations can be debated, but the undeniable result is that a large strategic component of Canada's economy will be supplied by others on their terms!

How and why did this happen, and could it have been prevented?

With hindsight one can distinguish structural, bureaucratic and political reasons why the fusion program was cancelled at that particular time.

The program had three very good features, in principal strengths but also weaknesses. It was demonstrably good science. It was helping develop a new source of energy with no greenhouse gases, and it was showing good results in technological development and private sector involvement. However, the first and third features fall in the mission of Industry Canada, and the program was funded by Natural Resources Canada (NRCan). At that time, NRCan had not even begun to understand the greenhouse gas problem and the real issues involved. This was also at a time when the public appreciation of the climate change issue was really minimal.

One must also not forget that in a government or similar large organization, no department ever says anything really positive about a program funded by another if there is any affinity. The inevitable penalty for such an indiscretion is to be given the mandate for the program without the budget. Industry Canada therefore always downplayed the science aspects and the industrial benefits of the fusion program, mostly on the basis of unfounded innuendo, and NRCan appeared to enjoy promoting the burning of oil and gas and doing research on coal. There was also one humorous explanation from the Minister of NRCan who stated that the fusion program had such good industrial benefits that it no longer needed federal government support!

The main trigger for the cancellation of the National Fusion Program was, however, the process of Program Review II, motivated by the requirement to reduce government expenditures.

There was, however, no technical review of the program to see if its objectives were valid and being met. The fundamental structural fault in the process was that the program's "advocate" was AECL, who had inherited the program from the NRC twelve years previously, but which never had any technical commitment to fusion, even as a very long term option. From as far back as the 1970's. AECL was always very leery of the "mandate without budget" effect, just discussed. This explains part of their complete lack of corporate backing for fusion research. Of course, the Nation Fusion Program Office at AECL supported us all very well, but without any enthusiasm from above. It is my opinion that had the agency been NRC, a manager of many of Canada?s scientific installations, a way would probably have been found to save at least a part of the program.

AECL had no real interest in saving the program and every understandable interest in using the money to reduce the impact of the budget restrictions on its own "in house" programs, which the press releases of the time clearly show that it did.

Another problem is that in Canada there was not, and still is not, to my mind, any valid evaluation process for large scientific installations. To some extent, the federal government has now realized the absolute folly of its neglect of longer term science and technology research and has responded by some useful though as yet very incomplete gestures such as the Canadian Foundation for Innovation, and increased budgets for the Granting Councils. It still, however, seems to regard larger scientific projects as having no intrinsic merit, but definitely having political "plum" value.

There was even a negative "plum" value effect when the fusion program was cancelled. The Minister of Energy, a lawyer from the Oil Patch and an enthusiastic supporter of Plan B, appeared pleased to be able to stick it to Qubec, while diverting criticism by saying that she was sticking it to Ontario as well. What a wonderful way to insure the technological future of the country!

Much of the responsibility for the disaster must also taken by the Quebec and Ontario partners in the fusion program's research centres. There would have a better chance of saving at least part of the program if the provincial governments and utilities concerned had reacted vigorously and in concert to the federal decision. This was not to be. Ontario Hydro was in turmoil at that time and Hydro-Quebec had just had its "social" mandate for technology development removed and this mandate was not given to any other organization nor assumed by anyone.

One can make a very convincing argument that society as a whole should have a fusion research program but one cannot really argue that a particular utility must. At the time of the crisis, the Quebec government promised help at very high level but in the end delivered nothing.

In the end the federal government gave 19 million dollars to finish some aspects of CCFM's experimental program, to decommission the experimental facilities and to redeploy its personnel over a period of about three years. The Quebec partners, Hydro-Qubec and INRS, verbally agreed to match this money and signed a new agreement to cover the 3 year phasing down program, which was carefully optimized and planned to maximize the results and minimize the effect on the personnel.

The Qubec partners soon became fixated by the idea of using this federal money for their own purposes. About a year into the new phase, with no advance notice, the Qubec partners radically shortened the experimental time left for the tokamak, wasting a year's experimental preparation time and all the significant related expenses. They simultaneously cancelled the redeployment and diversification program. As can be imagined, this had a very negative effect on the personnel. Hydro-Qubec and INRS then proceeded to have a complete falling out and ceased all real collaboration on diversification projects.

The Tokamak, which took 20 years to build and improve to a high level of technical excellence, is now apart and in boxes. An up-to-date 70 million dollar installation has been scrapped and wasted. The tritium technology development industry has lost a main focus. Two active and well practised teams, at CCFM and CFFTP, have been disbanded, and many careers have been destroyed or prematurely terminated.

Do I have any conclusions? Or better put, do I have any printable conclusions? Am I bitter? Are we bitter? If so, against whom? Against the federal government and its agencies? Against our "home" institutions who did not support us and even knifed us in the back? I suppose a bit of all of the above.

I think my main negative emotional reaction is sadness, sadness at a missed opportunity for Canada, for what could have been. There are also great positive memories - pride at what we managed to accomplish and pride at the recognition of Canada capabilities that came from abroad. Pride even that our colleagues abroad could not believe that any government could be so stupid!

Pride and sadness, both honourable emotions - Thank you.

Call for Papers

Twenty-First Annual Conference of the Canadian Nuclear Society

A Better Nuclear Tomorrow

Delta Chelsea Hotel, Toronto, Ontario, Canada
2000 June 11-14

The Canadian Nuclear Society's 21st Annual Conference will be held in Toronto, Ontario, Canada, 2000 June 11-14. The location is the Delta Chelsea Hotel, close to the heart of Toronto's theatre and restaurant district.

The main objective of the Conference is to provide a forum for discussion and exchange of views on the technical aspects and the benefits of nuclear technology. **Papers on new applications and novel processes, advances in physics and engineering, and the technical aspects of plant performance are particularly encouraged,** but papers are of course invited on technical developments in all subjects relating to nuclear technology, including:

- medical applications
- reactor physics, fuel cycles
- thermalhydraulics, safety, licensing
- plant aging and life extension
- fuel design
- computer-code validation, software QA
- manufacturing
- radiation transport, shielding, health physics
- probabilistic risk assessment
- fission-product behaviour, severe accidents
- advanced reactors, research reactors
- reactor performance, inspection and maintenance, reactor decommissioning
- operator training, simulators
- robotics
- nuclear waste management, environmental issues, transportation and storage of nuclear material
- industrial irradiation
- uranium mining
- fusion, particle and condensed-matter physics.

General Information for Authors

- Deadline for receipt of summaries: 2000 January 7.
- Notification of acceptance: 2000 February 15.
- Deadline for receipt of full papers: 2000 April 21.

Content of Summaries

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

The summaries should include:

- an introductory statement indicating the purpose of the work
- a description o f the work performed
- the results achieved
- a closing statement summarizing the significant results.

Technical Program Chairs for the Conference are Aniket Pant (Zircatec) and Jad Popovic (AECL).

Summaries should be submitted to:
CNS Annual Conference 2000
c/o Jad Popovic **AECL**
2251 Speakman Drive
Mississauga, Ontario
Canada L5K 1B2

Telephone: **(905) 823-9060 Ext. 4709**
Fax: **(905) 822-0567**
E-mail: **popovicj@aecl.ca**

GENERAL news

(Ed. Note: The following news items have bee drawn from various sources.)

AECB renews Bruce B licence

At its October 7, 1999 meeting, the Atomic Energy Control Board renewed the Operating Licence for Ontario Power Generation's Bruce "B" nuclear station for the typical two year period. However, in what has become the AECB's "slap on the wrist", it has required OPG to report back to the Board every six months on its progress in addressing various issues of concern to the Board, including a backlog of maintenance work

The Board also granted Cameco a two year Operating Licence for the McArthur River uranium mine and for the transport of the ore to the Key Lake facility for milling.

The October 7 meeting, which was held in Port Hope, Ontario, the home of Cameco's uranium refinery, proved to be an emotional one. In the context of the Board's initial consideration of a licence renewal for the refinery, residents, still angry about the contamination throughout the town from earlier operations of the refinery (when it was owned by the crown corporation Eldorado Mining and Refining) spoke with anger and tears about the effect the refinery had on their lives. Patricia Lawson, a long-time critic of the refinery and the nuclear industry in general, brought a personal message that her adult daughter had a brain tumour. AECB president, Agnes Bishop, empathized with the residents but commented that the Board had to separate judgement of current operation from those of the past.

At its previous meeting in August, the AECB approved conditional Operating Licences for the Maple 1 reactor and for the associated isotope processing facility. Maple 1 is the first of two 10 MW(th) reactors being built by Atomic Energy of Canada Limited at Chalk River for MDS Nordion specifically for isotope production. The Operating Licences are conditional in that AECL is required to provide additional documentation and specific approval is required from AECB staff before fuel loading. It is expected that Maple 1 will start up in early 2000 and Maple 2 late in that year.

COG appoints new president

In September, CANDU Owners Group Inc. appointed a new president, Patrick Tighe. He replaces John Sommerville who acted as interim president during the restructuring of COG into an incorporated organization.

Before taking on his new role Patrick ran a management consulting business in Ottawa. Prior to that he was president of ABB Canada, Power Generation Segment. Earlier he worked for Atomic Energy of Canada Limited, at the Whiteshell Laboratories from 1974 to 1978, at Sheridan Park until 1986, as executive assistant to AECL's president, then as senior technical officer at the AECL office in Seoul, Korea. He graduated from Royal Military College in 1970 and was in the Canadian navy until 1974.

Test for severe reactor accidents

The Nuclear Energy Agency (NEA) of the Organisation for Economic Co-operation and Development (OECD) sponsored a large scale test in Russia in July involving melting fuel of a light water reactor (LWR). During the test core material was heated to over 2500oC for 3 hours. The test vessel was cooled externally to simulate conditions of a severe accident. Safety organizations from most OECD countries are analysing the results with the aim of developing better computer modelling programs. A conference will be held in Germany in late 2000 to present the results of the work.

(For further information contact NEA at < news.contact@nea.fr > or see their web site <www.nea.fr >).

CNF has new Web site

The Canadian Neutron Facility for Materials Research (CNF) has a new bilingual web site. The CNF is a 40 MW(th) pool-type research reactor, based on the MAPLE design, being proposed to government by Atomic Energy of Canada Limited and the National Research Council, as an ultimate replacement for NRU. The site, administered by NRC, is at < http://www.cnf.gc.ca > (English) or < http://www.ccn.gc.ca > (French). The site includes a description of the CNF project and a sample letter of support that can be used to fax/mail to politicians and others who may be able to influence the project's success.

Federal government seeks science advice

The federal government is seeking comments on a report entitled, *Science Advice for Government Effectiveness (SAGE),* which was prepared by the Council of Science and Technology Advisers.

The Council is a group of 21 senior scientific, academic and corporate individuals, set up to provide the Cabinet Committee on Economic Union with external expert advice on internal federal government science and technology issues.

The report sets out a number of proposed principles and guidelines for government decision makers on the identification of issues requiring science advice and the method of obtaining sound, objective advice.

Copies of the report can be obtained from the Council's secretariat, which is housed in Industry Canada. The e-mail address is: < csta.cest@ic.gc.ca >

In response to an invitation from Jean McCloskey, Deputy Minister, Natural Resources Canada, the Council of the Canadian Nuclear Society has submitted comments, basically endorsing the thrust of the report.

Changes at Ottawa

Just as this issue of the *CNS Bulletin* was going to press it was announced that Jean McCloskey, Deputy Minister, Natural Resources Canada is being transferred to a position in the Privy Council Office (the central office of the federal government). Her replacement is Dr. Peter Harrison, who was Head, Leadership Network in the Privy Council Office. His previous appointments were with the departments of Human Resources, Indian and Northern Affairs, and Finance. Harrison has a Ph.D. in Geography.

In another move of interest, Dr. Leonard Good, formerly Deputy Minister of Environment Canada has been appointed President of the Canadian International Development Agency. Good was one time Associate Deputy Minister of the Department of Energy, Mines and Resources (the previous name for Natural Resources Canada).

New Act deferred (again)

The Atomic Energy Control Board has revealed that the *Nuclear Safety and Control Act* will not be proclaimed until some time in the year 2000.

The new Act was passed by Parliament in March 1997. However a number of steps are necessary before the Act can be put into force. Key milestones for the promulgation of the Act include:

- Approval in principle of the regulations by the Board;
- Review and approval by the Governor in Council (Cabinet);
- Act proclamation followed immediately by a meeting of the Commission at which time the Regulations are made.

The AECB staff have prepared drafts of the necessary new (or modified) regulations required under the Act. The majority of those needed were issued in 1998 for comment and many comments were received. Early in 1999 the proposed Regulations were posted officially in the Canada Gazette and many more comments were submitted. The AECB reports that its staff are "well advanced with the process of reviewing" the comments.

At the time of writing no schedule had been announced for AECB staff to present revised Regulations to the Board.

AECB releasesAnnual Report

The Atomic Energy Control Board has released its Annual Report for the fiscal year ending March 31, 1999.

In that fiscal year the staff complement increased 2.6% to 390 and overall expenditures increased to $53.9 million from $48.1 million the previous year. Approximately 74% was recovered from licence fees. The category of Reactors and Heavy Water Plants cost $29.0 million of which $25.7 was recovered through fees, or 89%.

The report makes a number of comments on the nuclear scene, expressing concern about the lack of young people in the field, the reduction of research and development, and the potential effect of electricity deregulation.

Copies are available, free of charge, from the AECB. The e-mail address is: < info@atomcon.gc.ca >.

Small D2O spill at Wolsong 3

On October 4, a spillage of heavy water occurred at Wolsong-3 during maintenance and safety checks. About 40 to 50 litres of heavy water were spilled during de-assembly of a moderator pump and was contained within the plant. Reportedly 22 workers were in the reactor building at the time, but there were no indications that any of them suffered any radiation exposure above authorized limits.

Discovery of Ore Deposit

The discovery of a new high-grade uranium ore deposit in northern Saskatchewan has been announced by Cameco Corporation. It is at La Rocque Lake, about 55 km northwest of the Rabbit Lake mine.

As of August 1999, 42 exploratory holes had been drilled, with one showing ore concentrations of close to 30% U_3O_8. Further drilling will be done to delineate the size of the ore body to determine if it is economically minable.

Criticality accident in Japan

A criticality accident occurred at JCO Ltd's fuel conversion plant in Tokai Mura, Japan, at about 10:35 am, local time, on September 30, 1999. The incident happened in the experimental conversion building as workers transferred uranyl nitrate into a sedimentation tank.

JCO - a subsidiary of Sumitomo Metal Mining Co Ltd - was processing the nuclear fuel component for the Japan Nuclear Cycle Development Institute's Joyo experimental fast breeder reactor, at a uranium enrichment level of 18.8%. The amount of uranium liquid fed into a container should have been limited to 2.4 kg, but 16 kg of liquid was reportedly fed into the tank, initiating a criticality reaction.

By midnight water had been drained from a cooling jacket around the tank (which was acting as a neutron reflector)and had added boric acid (a strong neutron "poison") to the tank

Three workers performing the operation received excessive radiation doses. Initially it was reported that a further 46 people, including 33 JCO employees and three firemen, were treated for radiation exposure. Later reports increased the number to 69. Radiation levels of 0.84 mSv/h were recorded around the facility immediately after the accident. Over 150 local residents were evacuated, while residents within a 10 km radius of the plant were told to stay indoors. Access to an area within a 200 m radius of the plant was restricted.

The accident was provisionally rated by the Japanese Science and Technology Agency (STA) at level four on the International Nuclear Event Scale (INES) established by the International Atomic Energy Agency. Later, Japanese authorities 'unofficially' upgraded the accident to INES level 5, classifying it as an 'accident with off-site risk'

Initial investigations into the cause of the accident suggested that safety procedures were regularly being violated and workers had insufficient training. The official operation manual approved by the government was apparently being ignored, with uranium oxide (U3O8) powder being dissolved in stainless steel buckets, instead of in purpose-built equipment.

Further investigations determined that company-sanctioned rules had been violated and that the staff were insufficiently trained.. Reportedly, workers were instructed to skip a vital procedure in the 'wet' conversion process, which would have enabled precise control in transferring the uranyl nitrate solution. Instead of carefully adding the uranyl nitrate into a verification tank, it was poured directly from buckets into the precipitation tank. It was reported that the workers aimed to 'complete the work, which takes about three hours under normal procedures, within 30 minutes'. Other reports said the workers had previously skipped the step without incidence.

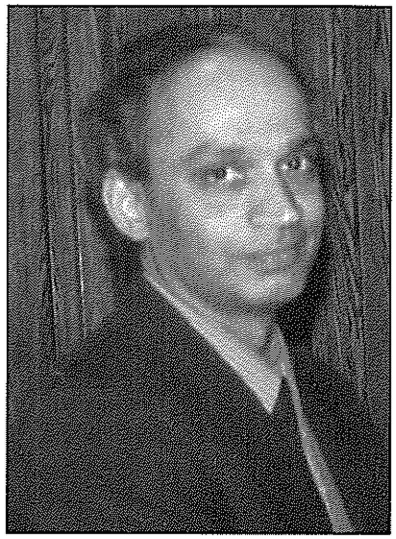
A team of three nuclear safety specialists from the International Atomic Energy Agency went to Japan during the week of October 11 to determine the facts relating to the criticality accident. Their report is expected to be released in mid November.

CNS news

From the President's desk

Our Society is now into its 20th anniversary and just completed its first year as an independent not-for-profit organization. Therefore it is time for some reflection. Also, we need to prepare ourselves to meet upcoming challenges as we march ahead into the next millennium.

What are challenges facing us? The main concern is public opinion of nuclear science and technology (NST). As a society, it behooves us to increase public awareness of the benefits of NST. It does not matter how much convinced we in the industry are about the positive aspects of NST. At the end of the day public awareness and acceptance will rule. So what has your Society been doing about it?



Kris Krishnan

Well, we have regularly been organizing courses, conferences, seminars and workshops of interest to our members. There is some non-member representation at these events. However, we are largely talking to ourselves in these forums.

In my mind, a significant service that your Society has started doing since the summer of last year is the course on Science of Nuclear Energy and Radiation (SoNEaR). Two sessions were held so far — one at McMaster University and the second at the University of New Brunswick at Fredericton. More than 30 high-school science teachers from various parts of Canada attended these sessions. All attendees have commented favourably on the courses. Also, the New Brunswick Department of Education Science Coordinator has requested that the course be repeated. We hope that the teacher attendees disseminate in their classrooms the information they gathered from the courses.

Sheridan Park branch chairman, Parviz Gulshani (L) presents a CNS 20th Anniversary "Inukshuk" to Ontario Minister of Energy Jim Wilson while CNS president Krish Krishnan looks on, at a special branch meeting, September 28, 1999.

The second task ahead of us is to increase the membership base. There are just over 800 members in the CNS. This is but a small fraction of the number of people working in the nuclear and related industries in Canada. So please encourage your friends and colleagues to join the CNS. It is volunteer work, it is serious, it is rewarding and it is fun. This year, to celebrate its 20th anniversary, the CNS will be giving away 20 beautiful Inukshuks in a draw for members in good standing for the year 2000 by 1999 December 10 (see notice elsewhere in this Bulletin). So renew or join early and be eligible for the draw!

V.S. (Krish) Krishnan
President, Canadian Nuclear Society

CNS Course for teachers

The Canadian Nuclear Society sponsored a four-day summer course, July 24 to 27, 1999, at the University of New Brunswick in Fredericton. Organized by Clair Ripley, Education Coordinator for Atomic Energy of Canada Ltd. in Atlantic Canada and Mark McIntyre of Atlantic Nuclear Services and New Brunswick Chairman of the Canadian Nuclear Society, the course was entitled "Science of Nuclear Energy and Radiation".

Fifteen teachers took part in the program: two from Newfoundland, three from Prince Edward Island, three from Nova Scotia, and the remaining seven from New Brunswick. Classroom lectures were interspersed with field trips, laboratory sessions, workshops and discussion groups.

Lecture topics ranged from an "Introduction to Health Physics" to "Nuclear Safety Concepts" to "Used Nuclear Fuel Storage " and "Risk Assessment". During a field trip to Point Lepreau the group was greeted by Bill Pilkington, Station Manager and Rod White, NB Power Vice President then received a technical tour of the facility, including a visit to the control room.

A reception /supper was hosted by Clair and Anna Ripley at their home in Queenstown on Friday evening July 23 for the resource people and organizers. It was an occasion for the various participants either to make or to renew acquaintances. On Saturday evening, CNS NB Chairman, Mark McIntyre was host at a banquet sponsored by AECL at the Lord Beaverbrook Hotel, Fredericton. The evening provided an opportunity for mingling of members of New Brunswick's nuclear industry with course participants. Dr. Douglas Boreham of Chalk River Labs was guest speaker, Mayor Walter Brown of Fredericton brought greetings from the city and Paul Thompson, Past President of the CNS was in attendance. The atmosphere was relaxed and friendly, a good break in a tightly packed schedule.

In assessing the four-day event, teachers commented on the various aspects of their experience regarding the facilities, the content and presenters of the material, and the field trips. The depth of their evaluation was noteworthy and one of the most significant points was that many added that they were anxious to recommend the course to their fellow teachers.

BRANCH ACTIVITIES

Some of the CNS Branches have actively begun the 1999 - 2000 season, while others are still in the organizing stage. Following are brief reports from the Branches as of late October. Branch chairs are given in parenthesis.

Officers' Seminar

Each fall for the past several years the CNS Council has held an "Officers' Seminar" to which representatives of the branches are invited. This year it was held on September 10 at the Sheridan Park Conference Centre.. Representatives from the Bruce, Chalk River, Golden Horseshoe, New Brunswick, Ottawa, Pickering, and Sheridan Park branches attended and participated in discussions on issues of mutual interest.

Chalk River (Al Lane)

The Chalk River Branch held its Annual General Meeting Thursday, October 21, at the J. L. Gray Centre in Deep River. As part of the AGM, David Cox made a presentation entitled: *"Swords into Ploughshares: Nuclear Weapons Destruction and the CANDU MOX Fuel Option - The role of AECL and Chalk River"*

Golden Horseshoe (David Jackson)

On October 12, the Golden Horseshoe Branch held a seminar by Ray Silver, the well-known nuclear journalist. Ray gave an excellent talk on "The Canadian Impact of the Hiroshima Complex". The seminar, which was held in conjunction with Dave Jackson's course on Science and Technology in the Media, was very well attended and well received.

Manitoba Branch (Morgan Brown)

The Manitoba Branch of the CNS had a successful kick-off to its season, with a talk presented by long-time nuclear reporter Ray Silver (accompanied by his wife Lynne) on September 23 and 24, 1999. Ray talked about the "Hiroshima complex", and how paranoia and guilt regarding nuclear weaponry has hamstrung the nuclear industry in Canada and around the world. He didn't mince his words, especially with respect to the government and the "doomsayer industry" (anti-nuclear activists)!

The talk was attended by about 40 people at Whiteshell Laboratories (unfortunately there was a conflict with a high-priority day-long quality assurance training seminar), and another 25 at a joint CNS/University of Manitoba Physics and Astronomy Department colloquium. This is the second joint venture with the Dept of Physics and Astronomy (the first was Beth McGillivray), and we hope to continue to foster our relationship.

New Brunswick (Mark McIntyre)

On Saturday September 25, 1999 the New Brunswick Branch of the CNS held their annual dinner. The event was well attended with over 60 people gathering at Saint John s legendary Union Club. The annual dinner is always the highlight of the New Brunswick branch program. This year, guest speaker Mr. R. Allen Kilpatrick, President and CEO of AECL, discussed the challenges, the opportunities and some of the successes of the Canadian nuclear industry.

Sponsors for the event were: Canadian Nuclear Society, Atomic Energy of Canada Limited, NB Power, Biron

Engineering International, Brunswick Nuclear Inc. and Atlantic Nuclear Services Ltd.

One of the special moments of the dinner was the presentation of the NB Branch Award to Clair Ripley, Educational Coordinator for AECL, Atlantic Region. (See separate article.)

The NB Branch of the CNS sponsored a talk by Patrick Reid, Analyst with ALARA Research, on the subject of CANFLEX Fuel, a fuel design that has the possibility to counter the affects of pressure tube creep and plant aging in general. The lecture was the kickoff session for the Continuing Education Weekend held by the Association of Professional Engineers of New Brunswick, on September 30, & October 1&2. Patrick s knowledge and presentation style made a good impression with the crowd of engineers. The APENB and CNS NB branch intend to continue to cooperate on initiatives that are of mutual benefit in the future.

Ottawa (Bob Dixon)

The Ottawa Branch has a new chairman, Bob Dixon. Former chair, Sadok Guellouz was inveigled away to work for AECL at Sheridan Park (where he is already active in Branch activities). Two new members have been added to the Branch executive, one from the AECB. The first meeting will be held Nov. 25 with Dr. Terry Rogers speaking on AECL's R&D advisory committee. Plans are still being developed for balance of the 1999-2000 season.

Pickering Branch (Marc Paiment)

Eduardo Lopez, our branch Treasurer, organized a CNS display for the "Pickering A Return To Service" Open House on October 2nd. Our branch has been a regular participant in the Pickering Open Houses. The booth was staffed by Eduardo, CNS President Krish Krishnan and Leslie Chrobak (again, many thanks to Krish and Leslie for coming out to lend a hand). Over 10 boxes of CAN/CNS information material was handed to the estimated 1000+ people who attended the Open House.

Sheridan Park (Parviz Gulshani)

The very active Sheridan Park Branch continued its activities through the summer. Following is a list of seminars and meetings held since July and planned for November.

- July 5. - Dr. George Bereznai, AECL professor of Nuclear Engineering, Chulalongkorn University, Bangkok, Thailand: *The Thai-Canadian Nuclear Human Resources Development Linkage Project,*
- August 25. - Brian McGee, VP of OPG Nuclear Integrated Improvement Program: *Managing Performance Improvement: the Integrated Improvement Program,*
- September 16 - Ngoc-Boi Dinh, Manager, NSSS Engineering, Wolsong 2/3/4 Project, AECL: *Wolsong 2/3/4 Success and Lessons learned,*
- September 28 - The Honourable Mr. Jim Wilson, MPP, Simcoe Grey, Ontario Minister of Energy, Science and Technology: *Importance of Ontario's Nuclear Industry, Ontario's Plan to Restructure Electricity Sector, and Opportunity for Nuclear Industry in Competitive Market,*
- October 13 - Dr. Dave Whillans, Senior Safety Scientist, Health Physics Department, OPG: *Risks from Radiation Exposure at Low Doses and Dose Rates: New Development,*
- October 20 - Keith Dinnie, Manager, Probabilistic Risk Assessment Department, OPG: *LOCA and Failure of ECC in CANDU Reactors: Severe Accidents or Severe Over-Reaction,*
- October 28 - Mike Taylor, Acting Director General, Reactor Regulation, AECB: *Developments in Power Reactor Licensing,*
- November 08 - John D. Dickie, VP Business Planning and Administration in Customer Support, Airbus Service Company in North America: *Re-Thinking Maintenance*
- November 10 - Delegation of scientists from France and Japan: *Is there any scientific justification to lower our regulatory dose limits?*

TORONTO (Adam McLean)

Based on registrations, the Toronto Branch is the largest CNS branch. Under the new Branch executive it has been very busy.

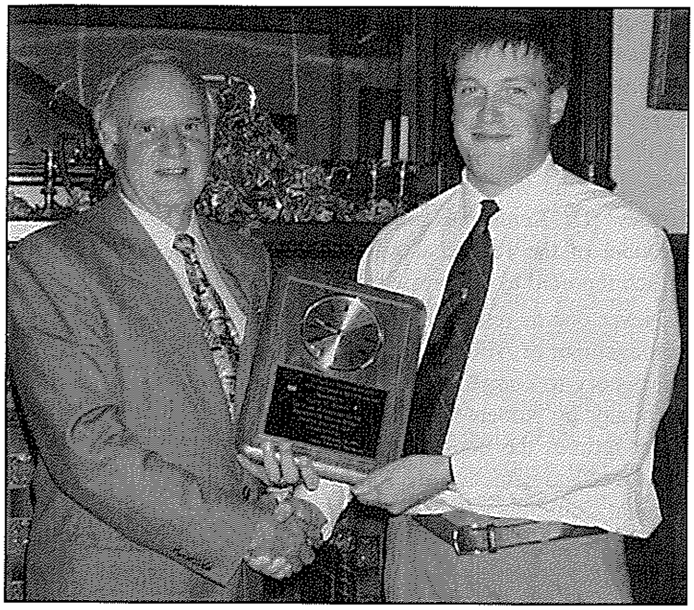
On August 23rd Dr. Aniket Pant from Ziratec give a virtual tour of that company's nuclear fuel fabrication facility. This took place at OPG's Hydroplace auditorium and had a warm welcome from both OPG employees and other CNS members. Attendance numbered approximately 50.

On October 20, the Branch and the University of Toronto Department of Chemical Engineering co-sponsored a public seminar at the University of Toronto, with G. Carl Andognini, EVP and Chief Nuclear Officer of Ontario Power Generation, speaking on "The Future of Electricity Generation in Ontario". This event attracted over 200 students, professors, OPG and AECL employees and other CNS members. Many applications for membership were distributed to spur support from the student population at the university.

Our most prominent future event is a marathon seminar by three visiting professors (Dr. Roland Masse of France, Professor Maurice Tubiana also of France and Professor Kiyohiko Sakamoto of Japan) on the topic of low level radiation risk. This talk is organized in conjunction with the International Centre for Low Dose Radiation Research of the Institute of the Environment, University of Ottawa and will take place November 11 from 12:30 - 2:00 at the Tanz Neuroscience building, room 6 on the U of T campus. It can be found just 50 metres North-West of the Queen's Park subway station.

The Toronto Branch web page *(found through the CNS home page)* has undergone EXTENSIVE update! The 'under construction' picture is gone and in it's place are links to branch contact information, the executive, links to Toronto area nuclear related web sites (updated constantly!), membership data, upcoming seminar information and past seminar announcements. Help in establishing a web page is offered to any branch.

Clair Ripley receives CNS award



Clair Ripley (L) and Mark McIntyre pose with the CNS NB award at the New Brunswick Branch dinner, Sept. 25, 1999.

Clair Ripley, AECL's coordinator of Educational Programs for the Atlantic Region, received the Canadian Nuclear Society New Brunswick (CNS NB) Branch Award on Saturday September 25, 1999. Mark McIntyre, CNS NB Branch chairman, presented the award to Ripley at the Branch's annual dinner, in the presence of Allen Kilpatrick, AECL's president and CEO, and the guest speaker at the event.

"The NB Branch Award is presented to a Branch member who has made a significant contribution to the nuclear industry in the area of nuclear science or in the area of education and communication," said McIntyre.

Ripley has organized conferences for practicing journalists, journalism students, and high school science teachers, and has spearheaded a series of educational outreach programs linking the community to the nuclear industry."One of Clair's passions is visiting classrooms to communicate nuclear science," said McIntyre. "Clair has spoken to more than 8,000 students in 32 schools all over the Atlantic region in the last year alone."

Ripley has experience in both education and politics. He was a science teacher and head of the Oromocto High School Science Department, as well as a part-time lecturer at the University of New Brunswick. Ripley also served as mayor and town councilor of Oromocto.

In accepting the award, Ripley spoke of his appreciation for the support received from the CNS in helping him deliver his educational programs throughout the Atlantic region.

The CNS NB Award is not presented every year, but rather when a deserving candidate attracts the attention of the New Brunswick branch executive. Previous recipients of the award are Sardar Alikhan, Dan Meneley, Bryan Patterson and Keith Scott.

Brian Cox - researcher emeritus

Dr. Brian Cox has been appointed to the position of Researcher Emeritus at AECL's Chalk river Laboratories.

Dr. Cox was at CRL from 1963 to 1988 in various roles, including Manager of the Materials Science Branch. From 1989 to the present he has been Chair of the centre for Nuclear Engineering at the University of Toronto. During his career he has made many contributions to the understanding of corrosion and hydrogen ingress processes in zirconium alloys.

Appointments at OPG

Pierre Charlebois, Senior Vice-President, Technical Services, at Ontario Power Generation Inc. has also been named *Chief Nuclear Engineer* replacing Warren Peabody. The Chief Nuclear Engineer is the Design Authority, accountable to the Chief Nuclear Officer (Carl Andognini) for engineering standards, engineering processes and the conduct of engineering to ensure that the plant design supports safe plant operation

Pierre has also taken on the postion of General Chairman for the 21st Annual conference of the Canadian Nuclear Society to be held in Toronto, June 2000.

John Skears, a long time employee of Ontario Hydro and now Ontario Power Generation, has been appointed Vice-President, Engineering Standards and Programs at OPG Nuclear.

Zanna Panton, new member of CNA/CNS staff.

Donald G. Hurst

Donald G. Hurst

Another pioneer of Canada's nuclear program has passed away. **Dr. Donald Geoffrey Hurst,** a distinguished scientist, international adviser, and former head of the Atomic Energy Control Board, died in Deep River Hospital on October 6, 1999, at the age of 88.

Don Hurst had a long and outstanding nuclear career in Canada and internationally, beginning at the Montreal Laboratory during World Was II and continuing until only a few years ago.

Don was born in St. Austell, Cornwall, England on March 19, 1911 but his family moved to Canada the following year. They lived in a number of Ontario communities, then to Buckingham, Quebec and finally Montreal. After attending schools in all of these communities Don went to McGill University where he obtained a B.Sc., M.Sc. and, in 1936, a Ph.D. in physics. He did post doctorate research at the University of California and Cambridge University before joining the National Research Council in 1939. In 1944 he moved to the Montreal Laboratory (operated by NRC) and in 1945 moved again when most of the members of the Montreal Laboratory set up the Chalk River project.

With Atomic Energy of Canada Limited (which took over the Chalk River Nuclear Laboratory when the company was formed in 1952) he was appointed Assistant Director, Reactor Research and Development in 1955 and Director in 1961. In 1967 he became Director of Applied Research and Development. On leave from that position he served two years as Director of the Division of Nuclear Power at the International Atomic Energy Agency in Vienna. In 1970 he was appointed President of the Atomic Energy Control Board.

Following "official" retirement as head of the AECB in 1974, Dr. Hurst was appointed chairman of the Senior Advisory Group of the IAEA and from then to 1985 oversaw the development of the large set of nuclear safety standards known as NUSS. Simultaneously, he served as Executive Director of the Royal Society of Canada from 1975 to 1977 and honorary executive director until 1985.

In 1987 he was an advisor to the Ontario Nuclear Safety Review (Dr. Kenneth Hare) and from 1990 to 1995 he was a member of the Technical Advisory Panel on Nuclear Safety which reported to the president of Ontario Hydro.

Never one to retire, in the early 1990s Don convinced the management of AECL to support the preparation of a technical history to complement the largely political history of the company by Robert Bothwell. With the collaboration of 15 other retirees the book Canada Enters the Nuclear Age was produced and launched at a special ceremony at the CNA/CNS Annual Conference in Toronto, June 1997.

Don Hurst received several awards, including an Outstanding Contribution Award from the Canadian Nuclear Association in 1990 and the prestigious W. B. Lewis Medal in 1996. The American Nuclear Society presented him with the "Tommy Thompson" Award in 1994 for his contributions internationally to nuclear safety..

Don was a long time member and strong supporter of the Canadian Nuclear Society.

He is survived by his wife of 60 years, Margaret, a son David of Toronto, and daughter Dorothy of Wellington, New Zealand.

A funeral service was held in the Deep River Community Church, of which he was a member, on October 12, 1999, with many former senior members of the Canadian nuclear community attending. Colleagues and friends remembered him as an excellent scientist, a mentor to many (including Nobel prize winner Bertrand Brockhouse), an intelligent administrator, a diplomat, and a very human but private person.

Richard Murphy

Richard Murphy, long term chairman of the Darlington Branch of the Canadian Nuclear Society passed away suddenly at the age of 46 on May 11th, 1999 at his home in Newcastle.

Rick worked for Atomic Energy of Canada Limited for 10 years at the Chalk River Laboratories and the Whiteshell Laboratories before joining Ontario Hydro. With OH, he worked first at the Pickering NGS in Reactor Safety before moving on to Darlington NGS. There, in recognition of his contributions and capabilities, he was selected for the Shift Superintendent-In -Training Program.

Rick was very active in the Newcastle United Church and took an active interest in the youth of his community as a member of the Big Brothers organization and as an assistant coach in minor hockey.

Rick will be sadly missed by his wife Ethlyn (Lyn) and his son Andrew. The caring and respect felt by family, friends and colleagues was evidenced by the capacity attendance and the kind words spoken at his memorial service which was held at the Newcastle United Church on May 14, 1999.

Beginnings of the CNS: looking back over 20 years.

Ed. Note: Much of the following is taken from an article "The Formative Years of the CNS", written by Phil Ross-Ross, with the aid of George Howey, and John Hewitt, all early presidents of the society, that was published in Vol. 13, No. 1, Spring 1992 issue of the CNS Bulletin. John Hewitt died, April 27, 1995, at the early age of 56.

As noted elsewhere in this issue of the *CNS Bulletin,* the Canadian Nuclear Society is celebrating its 20th birthday in the fall of 1999.

Formally, the "Canadian Nuclear Society / Société Nucléaire Canadienne" was born as the "Technical society of the Canadian Nuclear Association, on June 11, 1979. Although part of the CNA the Society was to be distinct from the Association and to be a learned society with membership open to individuals.

That formal step was the culmination of much work during the 1970s by the three people mentioned in the note above along with others including, Dan Meneley, Wladimir Paskievici, Joe Howieson, Ernie Card, Tony Colenbrander, Bob James, and then CNA General Manager, Jim Weller. There had been "third day" technical sessions at the CNA Annual Conferences beginning in 1973.

A *Pro Tem* Council was appointed for the first year, 1979 - 1980, headed by George Howey as president, John Hewitt, vice-president, Dan Meneley, secretary-treasurer. The first elected Council was created at the first Annual General Meeting, in June 1980, with the same president and vice-president and Bob James as secretary-treasurer. The first issue of the CNS Bulletin, as a newsletter, had been created by John Hewitt. At the second AGM in June 1981 Phil Ross-Ross was elected president, John Hewitt remained as vice-president, and Peter Stevens-Guille became secretary-treasurer. Ross-Ross served as president again in 1982-83, the only person to have been president for two years.

Over the years the CNS grew in size and activities. Membership began at a few hundred and grew steadily to reach a peak of about 1,000 in 1996 (dropping somewhat since then). From holding a "technical session" at the CNA Annual Conferences the CNS has, over the past 20 years held its own Annual Conference (up until 1998 in conjunction with that of the CNA), has organized many specialized conferences, and has presented a number of courses. Internationally, the Society is a member of both the International Nuclear Societies Council and the Pacific Nuclear Council and has bi-lateral cooperation agreements with 17 other nuclear societies around the world.

In one of the few disappointments of the society, a peer-reviewed, technical journal, the *Nuclear Journal of Canada,* was launched in 1987, under the editorship of Alan Wyatt, but abandoned a year and a half later because of disappointing revenues and potential continuing losses which the Society could not bear.

Despite its formal ties with the CNA the Society has always operated as a separate organization, albeit with considerable cooperation with the Association. Throughout 1997 action was taken towards formal separation and in early 1998 members voted overwhelmingly to incorporate the Canadian Nuclear Society as a separate, non-profit, corporation.

The Canadian Nuclear Society is well poised to enter the 21st century as a strong, vibrant, independent organization of professionals involved or interested in the Canadian nuclear program.

20th Anniversary Draw

The Canadian Nuclear Society was born in late 1979 and will celebrate its 20th anniversary this fall.

To commemorate this important occasion there will be a lottery draw for 20 jade-coloured , Inukshuks, 7 cm. high on a green-glass base. *(See Photo)* The base will be engraved with the CNS log and a text including the winner's name. This beautiful glass sculpture will be a keepsake and will grace any desk.

The draw will take place **December 15, 1999.** All members in good standing (memberships paid) for the year 2000 as of December 10, 1999, will be eligible and will be automatically entered into the draw.

The winners will be notified and their prize delivered following the engraving of their name on their Inukshuk. The list of winners will be published in the *CNS Bulletin* and posted on the CNS Web site.

CNS Inukshuk, 20th anniversary award.

CANDU OWNERS GROUP

R&D Program Manager COG Vacancy Notice

Background

CANDU Owners Group is a not-for-profit organization committed to establishing a framework for cooperation, mutual assistance, and the exchange of information for the successful support, development, operation, maintenance, and economics of CANDU technology. The members of COG include the three Canadian nuclear utilities, AECL and potentially all the offshore CANDU operators. The COG R&D Program consists of four Technical Programs – Safety & Licensing; Fuel Channels; Chemistry, Materials & Components; and Health & Safety. Each of these Technical Programs consists of a number of Projects that are managed on behalf of (and funded by) two or more of the Members. This position is for a 2-year term (which may be extended).

The Program Manager has responsibility for the development and marketing of research programs for designated technical areas, management of specific research contracts and supervision of COG R&D Program staff.

Specific functions include:

- Identifying common needs that require R&D
- Developing ideas and needs, with the assistance of others, into proposal requests
- Arranging and chairing Technical Committee meetings
- Reviewing proposals for research work with the Technical Committees
- Developing project agreements with defined scopes of work, budgets, deliverables, schedules, terms of payment, and funding shares
- Ensuring that the scope, schedule and cost of each projects is consistent with the intent of COG policies and the specific project agreement
- Issuing purchase orders in accordance with the terms and conditions of COG policies and project agreements
- Appointing Project Managers, as appropriate
- Ensuring that purchase orders are issued by participating organizations to cover the costs of projects
- Carrying out day to day liaison with representatives of participating organizations on administrative matters
- Providing timely progress reports and final approved reports for the research projects
- Receiving, reviewing and approving for payment all invoices for R&D projects
- Preparing , reviewing and amending R&D policies and procedures for adoption by COG

Selection Criteria
Essential Competencies

- Excellent communication skills, both written and oral
- Ability to foster cooperation among disparate groups from several organizations while working from a position of influence, not authority
- Self-starter able to work with minimal supervision, and able to motivate and drive others

Preferred Knowledge, Experience and Qualifications

- 4 year University degree in Engineering, Science or equivalent
- 8-10 years of work experience, some portion of which involved project management and/or business administration
- Knowledge of the principles of the CANDU nuclear power plant design and operation
- Familiarity with computer spreadsheet software and the ability to make effective use of computer databases

Location

The incumbent will work from the COG offices at 480 University Avenue, Toronto Ontario with some travel required.

This posting is intended to solicit expressions of interest. Potential candidates are encouraged to contact COG to obtain further information. All such contacts will be treated as confidential.

Candidates can contact the COG R&D :
Malcolm W. Hardie
CANDU Owners Group,
480 University Ave., Suite 200
Toronto, ON.
M5G 1V2

Phone: (416) 595-1888 ext. 118
Fax: (416) 595-1022
E-mail: malcolm.hardie@candu.org

When Memes Collide

by Jeremy Whitlock

The time has come to accept the "radiation perception" debacle for what it is: possibly the greatest experiment in behavioral psychology and cultural evolution of our time. I am quite certain of this, any remaining doubts being put to rest by several events these past few weeks.

Even hardened nuclearphiles had to shake their heads in the aftermath of the September 30 criticality accident at Tokai Mura, Japan. It wasn't so much the accident itself – although that inexcusable consequence of institutionalized stupidity was mind-boggling enough – as the apocalyptic rendering it received in the public mind and the media that feeds it. The phrase "worst nuclear accident in Japan" rolled off the lips of phlegmatic news anchors around the globe, with very few (if any) asking what the second worst accident was. Or, how dangerous is a technology whose worst national accident claims two or three casualties?

The accident called into question everything related to nuclear power. Greenpeace activists, at that moment dogging two MOX-laden freighters off the Japanese coast, did a double take at their unbelievable serendipity. Anti-MOX crusaders here at home hastened to draw parallels where there were none. The BBC broadcast two-year-old file footage of a previously damaged building at the same site, claiming to have evidence of the roof being blown off in the current accident. Few questioned this either – except industry insiders sharing back-of-the-envelope and rudimentary Monte Carlo calculations over the Internet (the BBC has since apologized).

And then a week later some heavy water at a CANDU plant in South Korea leaked into containment. Now, as any parent of diaper-age children knows, leaking into containment is not necessarily a bad thing, but immediately there were comparisons made with Tokai Mura and a national outrage. A band of well-meaning citizens held an overnight vigil outside the plant in protest of the "leak" and the environmental harm they presumed it to cause.

The point is not the overreaction, which is nothing new, but the speed with which overreaction took place. Not an eyelash is batted in the mental link between all things nuclear. The word "radiation" is now a pre-programmed keyword in the public consciousness, with immediate thought associations and even visceral response – much like "atheist", "Hitler", "sex", and "chocolate". The reaction is contagious and deeply rooted.

There is a word for this. In his 1976 book, The Selfish Gene, Oxford zoologist Richard Dawkins coined the word "meme" (pronounced meem) to describe a fundamental idea that replicates itself in other minds, driving cultural evolution in the same manner that genes drive biological evolution. An entire field of "memetics" has since been established, taking the concept far beyond Dr. Dawkins' original vision (one might say that memetics is itself a meme).

Like genes, memes need not be "good" to replicate; they need only survive. If they push the right buttons, make interesting conversation, sell advertising spots, or appeal to fundamental fears and/or attractions, they will spread like wildfire and ultimately effect cultural change. Organized religion is the granddaddy of all memes.

Recognition of radiophobia as a meme actually explains a lot. It explains the subtle arched eyebrow of a friend or relative as I try to explain what I do for a living. It explains why Homer Simpson's day job is a weekly gold mine for satirical Zeitgeist humour. It explains why Three Mile Island (no off-site consequences) is household knowledge while Bhopal, India (4000 immediate deaths, many times more permanent injuries) is not. It explains why otherwise staid journalists sprinkle nuclear stories with offhand phrases like "political explosion" and "public affairs meltdown" – their tongues are not even in their cheeks; such is the power of a meme.

In Ontario, it explains why mayors, native chiefs, and numerous followers will do their best in the near future to prevent the passage of two trucks carrying a pittance of plutonium MOX fuel through their communities. In doing so, they will happily let trucks full of chlorine, propane, gasoline, acid, and other unmentionables pass without question – all shipments with higher risk than the dreaded plutonium. "Plutonium kills", "no solution for nuclear waste", "nuclear cover-up" – these are all sub-memes of radiophobia.

To those weary of the drawn-out MOX battle, and similar battles, in Canada, such distinctions might appear academic. It is important, therefore, to recognize an interesting consequence of this line of thought: memes can be battled just like genes can. One approach is to introduce a "counter-meme" into the host material (the minds of the population), and an example that I find increasingly disturbing is the claim that radiation at low doses has a zero or even beneficial health effect.

Like the meme that it is, this attractive idea has infected hundreds if not thousands of minds, particularly within the global nuclear community. It is a potent meme; it drives some to accuse colleagues of job-protection and grant-hunting, should they stand in opposition (note the parallel with radiophobia). It seduces scientific minds into incomplete examination of the issue; often overlooked is the fact that the Linear No-Threshold (LNT) hypothesis was never meant to measure the health detriment of a specific small dose to a large population. It is a single, conservative yardstick for planning purposes, applicable over a range of radiation types, dose levels, and dose rates, and should not be criticized for its misapplication.

The fact that the LNT is not, in fact, "linear" but incorporates a change in slope by a factor of two at low doses (the "Dose and Dose Rate Effectiveness Factor", or DDREF), is very often overlooked as well. Why? Because the meme spreads faster when you speak of straight lines drawn to zero.

Other buttons are pushed: An analogy is often made to Aspirin, where LNT-type thinking is said to equate a hundred people popping one pill each, to one person swallowing a hundred pills. Catchy, but relevant only to the deterministic health effect of radiation, which indeed disappears as individual dose decreases, much like Aspirin.

Stochastic effects are another story, about which comparatively little is known at low levels. In this region the math showed us decades ago (see Goss, Health Physics, Nov. 1975) that it is likely impossible to statistically detect the incremental effects predicted by the LNT. Study after study, of ever-increasing power, seems to prove this out, and yet the lack of a statistical increase is often cited as proof of the LNT's invalidity. Given the original intent of the LNT, the opposite is closer to the truth. (One button often pushed concerns the disproportionate funding devoted to reducing radiation risk, and this is probably valid, but irrelevant to the validity of the LNT.)

Unless you believe that "the end justifies the memes" (sorry), it is better, I think, to look elsewhere in the gene analogy for a game plan. Why not battle radiophobia with meme-mutation: like genes, replication is not necessarily exact, nor should it be since mutation can be beneficial as well as detrimental. Let's put our creative minds to the question of how to use the meme's own replicating characteristics against itself.

One idea is meme-splicing: substituting a positive nuclear thought into an existing meme. This has had some success with climate change, and time will tell if the replication rate of the "meet-Kyoto-with-nuclear" meme is high enough for survival. We can do the same with particulate air pollution, land usage, job creation, food preservation, nuclear isotopes, neutron-based materials testing, and yes, nuclear disarmament. The upcoming MOX test at Chalk River does gain acceptance as people think of it in terms of weapons destruction – a slight (and more truthful) mutation on the ten or twenty negative memes that seem to surround this enterprise. As more people accept "some" nuclear activities, they will start to examine their other grievances more closely – and that is where cultural change begins.

The vehicle for meme-splicing is public communication, and the trick is to go slowly so that natural replication can work at its own pace. This approach definitely requires patience and subtlety. Moreover, it stands a better chance of success, I think, than hitting people over the head with the exciting news that radiation is now good for you, and it has the added attraction of maintaining internal scientific consistency at every step along the way. So have heart; the battle of memetic engineering has just begun.

CALENDAR

1999

Nov. 10 - 12 — **CNS Reactor Safety Course**
Mississauga, Ontario
contact: Ms. Anca McGee
AECL Sheridan Park
Tel: 905-823-9060 ext. 6540
e-mail: mcgee@aecl.ca

Nov. 14 - 18 — **ANS Winter Meeting**
Long Beach, California
contact: ANS Office
La Grange Park, Illinois
Tel: 708-579-8257
Fax: 708-579-8234

Nov. 16 - 18 — **International Topical Meeting on Nuclear Plant Instrumentation, Control and Human-Machine Interface Technologies**
(embedded in ANS Winter Meeting)
contact: Dr. R. M. Edwards
Unitersity Park, Penn., USA
Tel: 814-865-0037
Fax: 814-865-8499
e-mail: rmenu@engr.psu.edu

Nov. 17 - 19 — **Climate Change and Energy Options Symposium**
Ottawa, Ontario
contact: Duane Pendergast
AECL - SP
Mississauga, Ontario
Tel: 905-823-9060 ext. 4582
e-mail: pendergastd@aecl.ca

Nov. 29 - Dec. 3 — **International Symposium on Restoration of Environments with Radioactive Residues**
Arlington, Virginia, USA
contact: Ms. T. Niedermayr
IAEA, Vienna, Austria
e-mail: t.niedermayr@iaea.org

2000

March 19 - 24 — **6th International Conference on Tritium in Fission, Fusion and Isotopic Applications**
Augusta, Georgia USA
contact: Faye M. Williams
Westinghouse Savannah River Site
773 A
Aiken, S.C. 29808 USA
Fax: 803-725-2756
Website: www.tritium2000.org

March 22 - 23 — **Women in Discovery Symposium**
College Station, Texas
contact: Ms. Beth Earl
Texas A & M University
Tel: 409-458-1061
Fax: 803-725-2756
e-mail: bethearl@trinity.tamu.edu

Apr. 2 - 6 — **8th International conference on Nuclear Engineering (ICONE - 8)**
Baltimore, Maryland, USA
contact: Dr. Jovica Riznic
AECB Ottawa
Tel. 613-943-0132

April 9 - 14 — **International Youth Congress**
Bratislava, Slovakia
contact: Stanislav Rapavy
Okruzna, Slovak Republic
Fax: +421-805-5991-191

May 7 - 11 — **PHSOR 2000 ANS International Topical Meeting on Advance in Reactor Physics, Mathematics and Computation into the Next Millennium**
Pittsburgh, Pennsylvania, USA
contact: I.K. Abu-Shumays
Bettis Atomic Power Laboratory
e-mail: abushuma@bettis.gov

May 14 - 19 — **10th International congress of the International Radiation Protection Association**
Hiroshima, Japan
For info. Website:
www.convention.co.jp/irpa10
e-mail: irpa10@convention.jp

June 11 - 14 — **21st CNS Annual Conference**
Toronto, Ontario
contact: Ms. Jad Popovic
AECL Sheridan Park
Tel: 905-823-9060 ext. 4709
e-mail: popovicj@aecl.ca

June 18 - 22 — **ANS 2000 Annual Meeting**
San Diego, California
contact: ANS Office
LaGrange Park, Illinois
Tel: 708-579-8257
Fax: 708-579-8234

July 10 - 13

Plutonium Futures - The Science
Sante Fe, New Mexico, USA
For info.
Website:www.lanl.gov/Pu2000
e-mail puconf2000@lanl,gov

Aug. 6 - 11

10th International Symposium on Thermaldynamics of Nuclear Materials
Halifax, Nova Scotia
contact: Richard Verrall
AECL - CRL
Tel. 613-584-3311
e-mail: verrallr@aecl.ca

Sept. 24 - 28

Spectrum 2000 International Conference on Nuclear and Hazardous Waste Management
Chattanooga, Tennessee
contact: Spectrum 2000 secretariat
Tel: 865-974-5048
e-mail: spectrum2000@engr.utk.edu

Sept. 25 - 28

ICENES 2000: 10th International Conference on Emerging Nuclear Energy Systems
Petten, The Netherlands
contact: Dr. Harm Gruppelaar
Petten, The Netherlands
e-mail: gruppelaar@ecn.nl
website: www.ecn.nl

Oct. 15 - 19

12th Pacific Basin Nuclear Conference
Seoul, Korea
contact: Mr. Kyo-Sun Lee
KAIF
Seoul, Korea
Fax: +82-2-785-3975
e-mail: kaif@borna.dacoin.cc.kr

Nov. 12 - 17

ANS/ENS 2000 International Meeting
Washington, D.C.
contact: ANS Office
La Grange Park, Illinois
Tel: 708-579-8257
Fax: 708-579-8234

Our Nuclear Heritage: Are We In Danger of Losing It?

Ed. Note: The following letter was forwarded to the CNS Bulletin by Prof. R. L. Clarke of Carleton University. He has agreed to be a recipient of any responses to Prof. Williams' search. Clarke's e-mail address is: < clarke@physics.carleton.ca >. Prof. Williams' letter has been edited to fit the space available.

There is always a great deal of concern when old items of art or literature are lost or damaged, and quite rightly so. But can we say the same about old scientific writings. I refer not to work published in Journals, but rather to those many internal reports which often have no formal recognition and are circulated in an ad-hoc fashion.. Many have never been formally publ´y∞∞´≤@nevertheless®D∞inal. This matter was brought home to me when I decided to write an appreciation of the contributions to reactor theory by a talented group of Canadians in Montreal during the period 1943-1955. The earliest of these reports had the prefix MT (Montreal) and they later became CRT and AECL reports. But not all.

Recently I decided to investigate the feasibility of collecting all the MT reports together and having them published. My first approach was to Atomic Energy of Canada Ltd. Alas, the reports are not readily available and the Librarian at AECL could find no record of them, although it was thought that copies may be in some subterranean repository. I then wrote to the Library at AERE Harwell and received the 'chilling' reply that the reports had been disposed of (destroyed) due to lack of space in the Library. I realised that the people who wrote these reports were either dead or quite old. Nevertheless it was worth trying to contact them.

I was fortunate in contacting Dr Robert Clarke of Carleton University in Canada who has agreed to help and is attempting to track down the old authors in the hope that they may still have some reports (unlikely). and to see if AECL could find the originals somewhere at Chalk River.

So, I end with an appeal to anyone, old-timer, librarian, collectors of scientific memorabilia, etc, to write to me [or to Bob Clarke] if they know the whereabouts of any reports with the prefix MT or indeed any reactor theory report dated before 1950. I have a dream in which a parcel arrives at my home containing every MT report with a biography of the author.

Well we can dream can't we ?

M.M.R. Williams
Emeritus Professor of Nuclear Engineering, University of London.
2A Lytchgate Close, South Croydon, Surrey, CR2 0DX, UK

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1999

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CNS WEB Page

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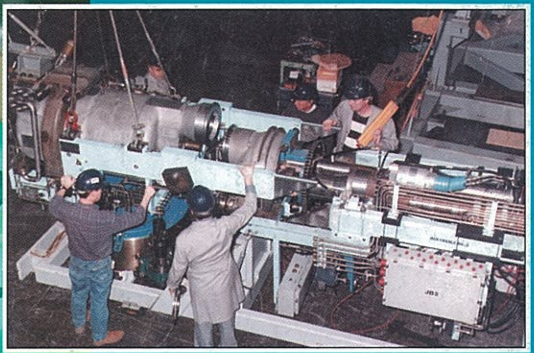
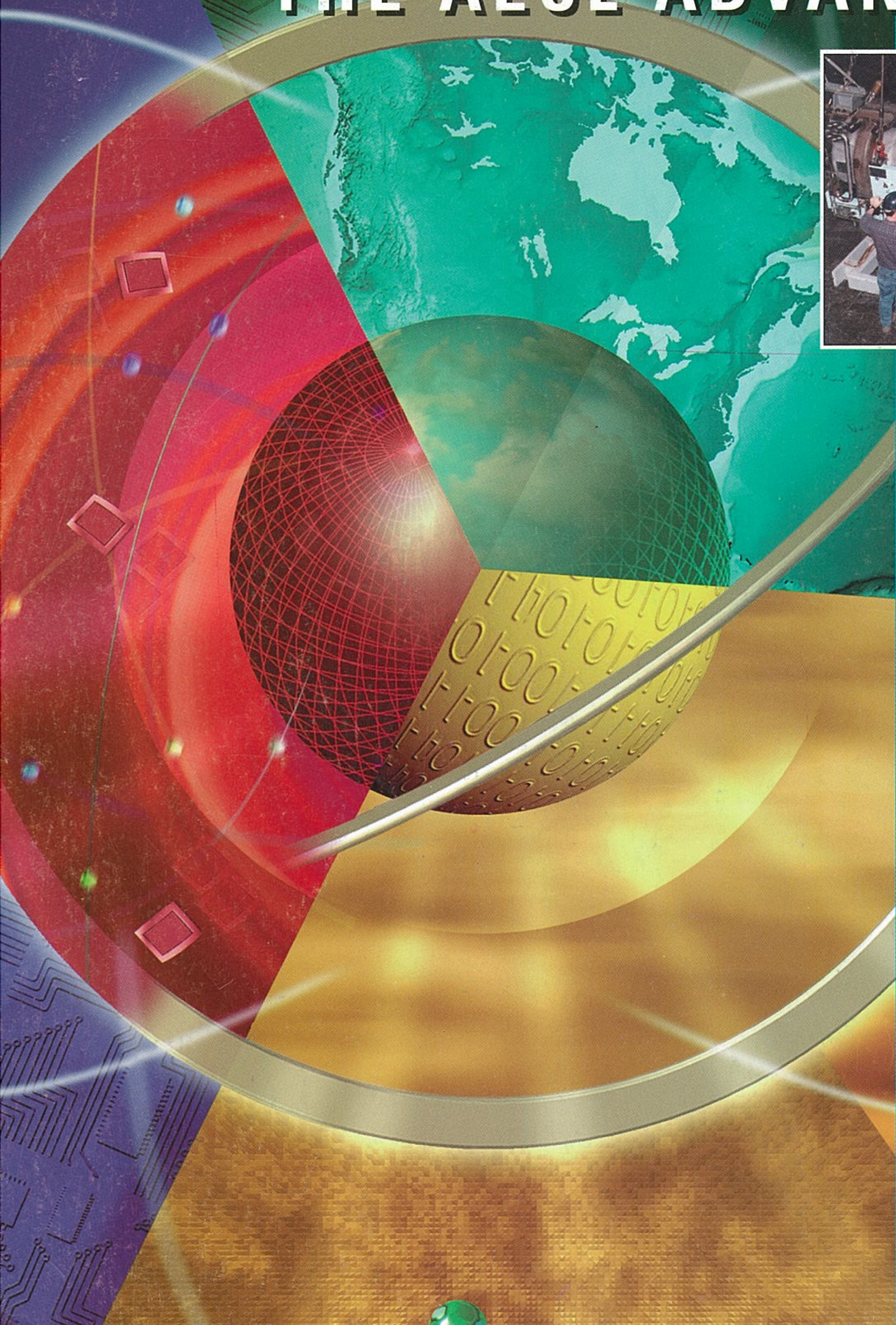
CANDU SERVICES

THE AECL ADVANTAGE





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