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Cover Photo

The photograph on the cover is a very recent one of the Chalk River Laboratories of Atomic Energy of Canada Limited showing the buildings housing the MAPLE reactors and associated isotope processing facility in the foreground.

(Photo courtesy of Atomic Energy of Canada Limited)

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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. Membership fee is $65.00 annually, $40.00 to retirees, free for students.

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EDITORIAL

A Mixed Record

This comment is written in the first person singular to emphasize the personal nature of the views expressed. Nothing here should be attributed to the CNS or any of its executive or officers.

As a concerned observer of the Canadian nuclear scene over several decades I have been intrigued by the swings in public and political support (or lack thereof) and often appalled by the response of the captains of our program.

The first two decades (starting from the Montreal Laboratory in the early 1940s) saw rapid scientific progress, supported by intelligent and decisive leadership. In less than 20 years, by the early 1960s, a demonstration nuclear power plant (NPD) was in operation, beginning the successful CANDU series of plants.

Over the next two decades (1960s and 1970s) the nuclear power program expanded dramatically, with new plants committed before their predecessors were completed. Then in the 1980s, problems, both technical and otherwise, began to appear. The former, such as the pressure tube failure in Pickering 2 in 1983, were soon overcome. Some of the others, such as the inquiry into dealings behind the Embalse and Wolsong 1 sales, the growing concerns about radioactive waste, and the cost of Darlington, grew and festered. As public attitudes turned negative industry leadership seemed to lose its way.

In the 1990s the domestic nuclear power program almost came apart. The seemingly interminable environmental hearing on deep geologic disposal came to an ambiguous conclusion. Ontario Hydro went through the embarrassing (to many of us) exercise of calling in American experts to correct problems resulting largely from inaction by its Board of Directors. Lawyers for AECL and Nordion argued until some sense was brought to bear. Surprisingly, the overseas picture was positive, with the successful fulfillment of the contracts for Wolsong 2, 3, and 4 and the beginning of the contract for Qinshan.

Turning to the present, the recent successful completion of Qinshan 1, ahead of schedule and on budget, was a marvellous achievement. It should have been actively and loudly proclaimed instead of being kept as a secret. Why the reticence? Are our leaders embarrassed with success?

It appears that Bruce Power will get Bruce 3 and 4 back on line before the summer peak demand and, although I remain sceptical, there is even a likelihood that the MAPLE reactors will begin operation (three years late). Unfortunately, the restart of Pickering A continues to slide.

Over the years the scientific and technical expertise to develop successful designs and to solve difficult problems when they arise has been demonstrated. The response to social and political problems has been disappointing, to say the least, and the record on the management side is very mixed.

Fred Boyd

IN THIS ISSUE

This issue includes both something new and something old.

Starting off is a report on the most recent CNS seminar under the title of **Protecting the Environment** because we felt the actual name of the seminar / workshop was too long. That is followed by the lead-off paper presented by Richard Osborne at that event using his title, **Protection of the Environment,** despite the obvious similarity.

Then we turn to the significant development of the fall, with our report **Waste Management Organization Underway,** followed by an account of an interview we were privileged to have with the head of the new Nuclear Waste Management Organization in **Conversation with Elizabeth Dowdeswell.** A recent paper on **Radioactive Waste Management at AECL** is included to round out that topic.

Two more of the excellent papers presented at the PBNC 2002 conference last fall are included. The first, on **The Maple Reactor Project,** we felt was timely because it looks as if the Maple reactors and the associated isotope processing facility may actually be given an operating licence this spring. The other is another paper by Romney Duffey, this time with a Chinese co-author, on the role of nuclear power in **Sustaining the Future.**

From the Simulation Symposium of last fall we present a paper, originally intended for the last issue, on **Thirty Years of Reactor Physics at Pickering.**

Then we turn to the old. Noting that December just past was the 50th anniversary of the NRX accident we felt that this should be remembered, not as an accident but as a learning experience and titled the first note **Learning the Hard Way.** This is accompanied with some excerpts of accounts of the event written almost a half century ago in **NRX Accident.**

Since this month (February) marks the 60th anniversary of the real beginning of the **Montreal Laboratory,** the remarkable group that began our nuclear program, we include some reminiscences by George Laurence, the senior Canadian.

There are some items which you may not have seen elsewhere under **General News,** and reports on your Society in **CNS News.**

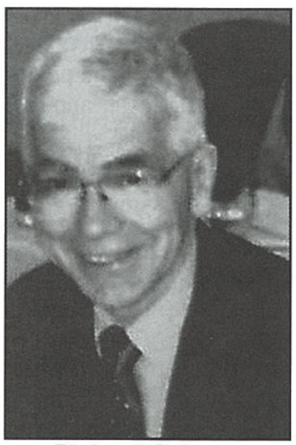
A page on **Books** is included along with an updated **Calendar,** and, of course, the inimitable words of Jeremy Whitlock in **Endpoint.**

We hope you find something of interest and invite your comments.

Protecting the Environment

CNS, CNA and COG join in a seminar and workshop on the effects of radioactive material on the environment

Judy Tamm



Richard Osborne

Doug Chambers

How to ensure protection of the environment from the effects of the release of radioactive material? That was the focus of a special seminar and workshop held in Ottawa, December 5 and 6, 2002. About 70 persons attended this specialized meeting.

The event had probably the longest name of any meeting in which the Canadian Nuclear Society was involved: *Canadian Perspectives on the Protection of the Environment from the Effects of Ionizing Radiation.* It was organized primarily by Judy Tamm co-chair of the Environment and Waste Management Division of the CNS along with Al Shpyth of the Canadian Nuclear Association and Peter Ernst of CANDU Owners Group. An impetus was the proposals from the Canadian Nuclear Safety Commission (CNSC) for new regulations. It was also somewhat of a follow-up of a seminar held in December 1996 co-sponsored by the CNS and the Canadian Radiation Protection Association.

The first day was organized as a seminar with papers providing overviews of relevant developments in Canada and abroad since the 1996 one. Based on that background the second day was devoted to a workshop with the aim of developing an industry perspective.

Richard Osborne, former director of biology at the Chalk River Laboratories of Atomic Energy of Canada Limited, was the lead off speaker. He provided a succinct summary of the many developments and initiatives over the past decade, beginning with a reference to the publication of the International Commission on Radiological Protection, ICRP 60, issued in 1991. That report stated the philosophy, which had prevailed until that time, that if man were protected others species would be also. Since then attitudes have changed.

Osborne noted several related meetings that had taken place since 1996, such as:

1996 - CNS/CRPA seminar on Impacts on non-human species;
- 1st International Symposium sponsored by Atomic Energy Control Board, Environment Canada and SRPI of Sweden, Stockholm

1999 - 2nd International Symposium, Ottawa

2000 - Workshop on Radioecology and Regulation, Dublin, Ireland
- IAEA Specialists meeting, Vienna, Austria

2001 - 2nd IAEA Specialists meeting, Vienna, Austria
- Principles and Ethics, Oslo, Norway

2002 - 1st NEA/ICRP Forum on Environmental Protection, Taormina
- Arctic/Antarctic Conference, St. Petersburg, Russia
- Radioactivity in the Environment, Monaco

The UN Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) had included a section on the effects of radiation on the environment in its 1996 report and has a program on the issue that will be included in its 2004 report. The International Atomic Energy Agency issued in 2001 a report TECDOC-1270 *Ethical Considerations in Protecting the Environment from the Effects of Ionizing Radiation* and is working on a Safety Guide. The ICRP has a Task Group studying the problem. Also the European Union has two programs under way: Framework of Assessment of Environmental Impact (FASSET) and Environmental Protection from Ionizing Contaminants in the Arctic (EPIC). *Osborne's full paper is reprinted in this issue of the* CNS Bulletin.

Osborne was followed by **Doug Chambers**, of SENES Consultants, who spoke from his background of vice-chair of the former Advisory Committee on Radiological Protection (ACRP) of the CNSC. CNSC president Linda Keen disbanded the ACRP along with its companion committee the Advisory Committee on Nuclear Safety a few months earlier. Just before its demise the ACRP had prepared and submitted a report related to the topic of the seminar entitled *Framework for Protection of Non-Human Biota.* Following assignment of a CNSC publication number the ACRP sent this report to a limited number of international organizations such as IAEA, ICRP, UNSCEAR. (The report was subsequently released publicly by the CNSC as report INFO-0703, accompanied by critical remarks from the

CNSC staff.)

The ACRP proposed that the objective of any protection scheme should be (1) to determine if releases of radioactivity represent an unreasonable risk to non-human biota, and (2) to ensure that populations of biota are reasonably protected. The ACRP recommended that realistic dose models be developed for reference biota. It proposed a three tier approach: concentration guidelines; dose rate criterion; evaluation of effects on actual biota populations.

Chambers concluded his presentation by noting that there were many issues to resolve, mentioning:

- What are we trying to protect ?
- What is a relevant endpoint ?
- What level of protection is adequate ?
- Assessment Methodology
  - Pathways Modelling
  - Dosimetry models
  - Reference dose
  - Natural background
- Monitoring to demonstrate compliance
  - Criteria given in dose but dose is not measured directly

The seminar then turned to presentations of papers on specific technical issues.

Carmel Mothersill,of the Dublin Institute of Technology, Ireland, spoke on *Low Dose Radiobiological Effects and Protectionof Biota.* She began by noting points to consider, such as:

- mechansitic difference between high and low dose effects
- interactions between radiation and chemicals
- cellular response
- genetic background
- ability of organisms to adapt

After providing details of some of her experimental work she closed with questions addressed to the scientific community and to regulators. To the former she posed:

- how to construct meaningful models given the complexity of biological systems
- how to do meaningful experiments.

To regulators she raised the following points;

- how to work to develop practical guidelines where compliance can be monitored
- how to get awat from the "safe dose" concept
- how to work with politicians, media, NGOs, etc. to develop realistic policieis
- how to explain that there may not be a "right" answer.

Tamara Yankovich, of AECL's Chalk River Laboratories, followed with a paper on *Developing Ecological Frameworks for Use in Risk Assessment: dose to biota through radionuclide exposure pathways.* Consideration of the following is required:

- radiionuclide levels inthe environmental media
- habitation occupancy
- uptake constants
- foodweb interactions

Patsy Thompson, of the CNSC, titled her presentation *Status Report on the CNSC's Regulatory Environmental Protection Program.* She stated that the CNSC draft regulatory standard on environmental protection policies and procedures requires that licensees manage their environmental protection program using policies and procedures with the following elements:

- a environmental protection policy
- planning
- implementation and operation
- checks and corrective action
- management review

The paper by **Nava Garisto,** of SENES Consultants, was on *Ecological Risk Assessment, Environmental Effects Monitoring and Radionuclides.* He noted that the old paradigm of "protect man and you protect the environment" breaks down in situations where an area is restricted to humans but not animals; there are different exposure pathways for non-human biota; other stresses (e.g., chemical) make biota more susceptible to radiation damage. He referred to ecological risk assessments his company had done for Cameco's Blind River facilties and OPG's Pickering plant and closed with comments on monitoring plans based on ecological risk assessments.

Don Hart, of Stantec Consulting Ltd (formerly Beak International) followed with a presentation on: *Ecological Risk Assessment, Environmental Effects Monitoring, and Radionuclides.* The risk assessment and effects monitoring are inter-related, the former indicating where there may be effects and the later identifying them.

Following all of these presentations, in mid afternoon the meeting moved to a panel discussion, chaired by Richard Osborne, involving some of the speakers plus Anar Baweja of Health Canada, Ken Dormuth of AECL, and Don Wismer, OPG. Dormuth commented that specific guidelines were needed for designers and operators.

The panelists noted that although we have the scientific and technical expertise to deal with the problem the eventual acceptance of "safety" or "environmental protection" in our society is a judgement by society meaning the public or its elected representatives. A challenge, therefore, is how to translate the scientific work into language understandable by politicians or the general public.

As noted above, the second day was in the form of a workshop led by Al Shpyth, in which about half of those attending the seminar participated. The discussion covered both regulatory issues and technical or operational ones such as how to do ecological effects monitoring.

Protection of the Environment from the Effects of Ionizing Radiation

- A Canadian Perspective of International Developments

by Richard V. Osborne[1]

Ed. Note: *The following paper was the lead off presentation at the CNA/CNS/COG Seminar on "Canadian Perspectives on the Protection of the Environment from the Effects of Ionizing Radiation", held in Ottawa, Ontario, December 5 2002*

Background

In 1996, the Canadian Nuclear Society and the Canadian Radiation Protection Association organised a seminar on the impacts of radiation on non-human species. That year marked the start of an increasing interest internationally on this topic. Three international symposia have been held; in Stockholm (1996, organised by regulatory agencies from Sweden and Canada), in Ottawa (1999, organised by regulatory agencies from Sweden, Canada and Australia), and in Darwin (2002, organised by the Australian regulatory agency in co-operation with the International Atomic Energy Agency (IAEA)). Interspersed with these symposia have been "specialists' meetings organised in Vienna by the IAEA in 2000 and 2001, and an international forum in Italy organised by the Nuclear Energy Agency in co-operation with the International Commission on Radiological Protection in 2002. These symposia and meetings have covered all aspects of environmental protection from ionizing radiation. Other meetings through this period have had narrower foci – for example, on the relationship of regulatory needs and radioecology (Dublin, 2000); on principles and ethics, (Oslo, 2001); on issues peculiar to protection of the Arctic and Antarctic environments (St Petersburg, 2002); and on radioactivity in the environment (2002 Monaco).

These events illustrate the level of activity that is now taking place as international and national agencies struggle to develop a framework explicitly for the protection of the environment from ionizing radiation. The adage that "protect man and you protect the environment" is no longer accepted as being self-evident.

What does environmental protection mean? What principles should govern it? How complete is the science base? An advisory group of the IAEA, faced with developing a draft safety guide on the topic of environmental protection, realised that there were no established answers to these questions. In its recent report [IAEA 2002], the advisory group showed how different world views, current scientific knowledge, and international law could be interpreted to give principles for protection that could be a base for developing a framework for assessment and management of risks to the environment from ionising radiation. A variety of international organizations are involved in developing the science base, in resolving technical issues, and in developing the framework. This presentation is an outline of the activities of those international organizations.

United Nations

As is pointed out in that IAEA report, much of the basis in international law and conventions comes from the activities of the United Nations. The UN Charter, itself [UN45] provides the first base:

> *"The purposes of the United Nations are... to achieve international co-operation... in promoting and encouraging respect for human rights."*

Although not referring to the environment the need to take account of differing viewpoints is established. Later, the World Charter for Nature [UN82] exhorts:

> *"Every form of life is unique, warranting respect regardless of its worth to man... Nature shall be respected and its essential processes shall not be disrupted."*

Here, a non-anthropogenic view is presented (*"regardless of its worth to man"*) but the most influential of the United Nations documents, the Rio Declaration on Environment and Development [UN92] is strongly anthropogenic in the obligations

1 Dr. Osborne was formerly Director of Biology at AECL Chalk River laboraties. He is now "semi-retired" and has his own company, Ranasara Consultants Inc., Deep River, Ontario

it places on member states. For example, it asserts that human beings are:

"... entitled to a healthy and productive life in harmony with nature."

Also, the environmental protection:

"... shall constitute an integral part of the ..."

sustainable development progress.

Further, States shall:

"... develop further international law regarding liability and compensation for adverse effects of environmental damage."

Such obligations point to *sustainability* and *environmental justice* being two principles underlying environmental protection.

Subsequent conventions and agreements have established internationally the importance of *maintaining biodiversity* and of *conserving habitats.*

The IAEA report [IAEA02] draws these ideas together and presents them as five principles for environmental protection from radiation. These principles can be stated [IAEA02a] as:

- Any radiation exposure should not affect the capability of the environment to support present and future generations of humans and biota. *(principle of sustainability)*
- Any radiation exposure should not have any deleterious effect on any species, habitat, or geographic feature that is endangered or is under ecological stress or is deemed to be of particular societal value. *(principle of conservation)*
- Any radiation exposure should not affect the maintenance of diversity within each species, amongst different species, and amongst different types of habitats and ecosystems. *(principle of maintaining biodiversity)*
- The management of any source of radiation exposure of the environment should aim to achieve an equitable distribution of the benefits from the source of the radiation exposure and any harm to the environment resulting from the radiation exposure, or to compensate for any inequitable damage. *(principle of environmental justice)*
- In decisions on the acceptability and appropriate management of any source of radiation exposure of the environment, the different ethical and cultural views held by those humans affected by the decisions should be taken into account. *(principle of respect for human dignity)*

Another agency of the United Nations, the Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), has provided the most complete, to date, international compilation of the effects of radiation on the environment. In its 1996 report to the UN General Assembly [UN96], it concluded:

"There is a wide range of sensitivities of plants and animals to ionizing radiation. In general, mammals are the most sensitive of the animal species, followed by birds, fish, reptiles and insects. The range of sensitivities of plants overlaps that of animals. Reproductive capacity, which is particularly important for the maintenance of the population, appears to be the most radiosensitive population attribute. for natural plant and animal communities, there is little evidence that doses rates of 0.1 milligray per hour (i.e., about 1000 times greater that the natural background) to a small proportion of the individuals (and therefore, lower average dose rate to the remaining organisms) would have any detrimental effects at the population level."

UNSCEAR is currently drafting a follow-up report that aims to define appropriate biotic endpoints for assessment, review methods for evaluating radionuclide transfer pathways in the environment and for estimating doses, and, perhaps most importantly, review evidence of impacts at specific sites. Publication of the report is expected in 2004 or 2005.

International Atomic Energy Agency

In 1992, the IAEA estimated the doses to plants and animals when emissions from nuclear facilities were at levels complying with radiation protection standards [IAEA92]. Although it could be concluded in those circumstances that plants and animals would be adequately protected there are clearly situations where protecting humans could be insufficient, such as when there has been intervention to remove humans from a contaminated area or in other circumstances where humans are not present. The IAEA examined the issues in a "report for discussion" [IAEA99], noting there that some countries had recognized the need for explicit demonstration of environmental protection but that there was no consensus on guidelines, endpoints and targets. In its follow-up, the IAEA has set out to develop a Safety Guide for environmental protection, publishing the report, noted above, on ethical considerations in protecting the environment [IAEA02]. As well as defining the principles for protection, the authors of the report discuss the different ethical views held by people that affect their view of the environment and its protection. The authors conclude that people who hold anthropocentric views, or non-anthropocentric views (biocentric or ecocentric) of the world could subscribe to the suggested principles though the relative weight given to each would depend on the particular viewpoint. For example, supporters of both anthropocentric and non-anthropocentric views could agree that the maintenance of biodiversity is a valid objective because of consequences for human interests or because of respect for the diversity of nature in itself.

The objectives of protection were seen as being to avoid radiation-induced early mortality, increased morbidity, reduced reproductive success, and deleterious hereditary effects. This is a set that is similar to suggested elsewhere (for example, in the FASSET program – see later) but with the important difference that scorable cytogenetic effects are not included; deleterious hereditary effects are. This change makes the set self-consistent and leaves scorable cytogenetic effects as a possible measurable indicator though even in this role there are difficulties in interpretation.

Other conclusions drawn in that IAEA report were that the ecocentric view of the world is likely to have increasing influence on environmental protection, that the practical emphasis will be on protecting populations, habitats and ecosystems, and that public involvement and informed consent will be important.

The IAEA is continuing with the development of the basis for a Safety Guide though formal promulgation of an actual document will have to wait for a revision of the IAEA Basic Safety Standards [IAEA96], which is unlikely to be started before the ICRP produces its new recommendations (see later). Its progress will be reported at the international conference to be held in Stockholm in 2003 October where the direction of Member States will be sought.

A separate activity of the IAEA is in co-ordinating research in a broad range of radiological-related areas. It is expected that a co-ordinated research program (CRP) will be set up for work related to environmental protection. Such a CRP would provide an opportunity for Canadian researchers to link with those elsewhere – as has been done in the very successful BIOMASS program that was the follow up to the BIOMOVS program in which staff in AECL, with the support of the AECB, were founding members.

International Commission on Radiological Protection

The International Commission on Radiological Protection (ICRP) has, until recently, been content to focus on the protection of humans. In its most recent general recommendations [ICRP91] it states:

"... the standard of environmental control needed to protect man ... will ensure that other species are not put at risk."

and

" ... individual members of non-human species might be harmed but not to the extent of endangering whole species."

There is now the recognition that, although these statements may be generally true, protection of non-human species does need to be addressed explicitly. The ICRP set up a Task Group in 2000 to recommend to the Main Commission (MC) how it might approach environmental protection. A draft of the Task Group report has been made available for comment on the ICRP website [www.icrp.org]. The Task Group reviews and discusses the issues involved; for instance, the development of reference flora and fauna, dose models and exposure geometries, the concept of "dose consideration levels", and frameworks for assessment and management. It generally concurs with the principles and objectives for protection as suggested by the IAEA advisory group [IAEA02] and recommends that the ICRP should develop a system of protection that explicitly includes protection of the environment, that it should provide an interpretation of radiation effects for use in setting criteria or benchmarks for protection, and that it should develop a set of primary reference fauna and flora. It is expected that the final report will go to the MC in 2003 for consideration as the MC prepares a revision to its general recommendations, expected in 2005.

Nuclear Energy Agency (OECD)

The Nuclear Energy Agency (NEA) has only recently been active in the development of a system for environmental radiation protection, starting with the meeting organised with the ICRP in Italy in 2002. The Committee on Radiation Protection and Public Health (CRPPH) of the NEA has had an on-going interaction with the ICRP, primarily through the ICRP's Committee 4 on the practical applications of the Commission's recommendations. The current work can be seen as a continuation of that interaction, providing a forum for feedback from the NEA Member States on the implications of the Commission's recommendations.

An important contribution by the NEA that has potential implications for environmental protection is a report, "The Way Forward in Radiological Protection" by an expert group, working under the CRPPH, prepared as a contribution to the debate on the future of radiological protection [NEA02]. The authors of the report urge the ICRP to revise its recommendations such that existing problems are fixed and that the system of protection evolves, rather than trying to create a new, revolutionary system. They recommend a process of "comprehensive authorization" that serves to achieve the same level of protection as does the current system in, what is claimed, a less confusing manner. What is important for environmental protection is that the comprehensive authorization process can be seen as fitting into the general framework used for the assessment and management of other risks to human health as well as of risks to the environment. Were a new system recommended by the ICRP to be along the lines suggested by the NEA expert group, then not only would harmonization of radiological protection of humans with protection against other risks be facilitated, but so also would be harmonization between radiological protection of humans and the environment.

The NEA is organizing another forum with the ICRP in 2003 in Lanzarote, Spain for there to be further exchange of ideas on this topic.

European Union

The Framework for ASSessment of Environmental ImpacT (FASSET) program is sponsored by the European Union and brings under one umbrella the work of 15 institutions in 7 European countries. It is, literally, a many faceted program as the acronym implies, covering research on radiation effects, the development of the idea of reference flora and fauna, dosimetry models, the establishment of a radiation effects data base, the identification of relevant biological effects and measurable endpoints, as well as the exploration of different frameworks for assessment and management. Progress reports have been made available on the program's website [www.fasset.org] and the final report from the program is to be presented at the IAEA's international conference in Stockholm in 2003 October.

A follow up to the FASSET program is being prepared under the sponsorship of the European Union. This program – Environmental Risks from Ionising Contaminants: Assessment and Management (ERICA) – will be substantially larger (~ Can$8 million) than the FASSET program. There would appear to be opportunity for the involvement within the ERICA program for researchers in Canada.

A related program under the auspices of the European Union is one that focuses on protection of the Arctic environment, the EPIC program (Environmental Protection from Ionising Contaminants in the Arctic). The emphasis is on detailing the transfer pathways in the Arctic, on identifying and detailing reference organisms for that environment, on developing the appropriate dosimetry models, on collation of Russian dose-effect data, and on determining appropriate criteria and standards.

Another European initiative relates to the OSPAR (Oslo-Paris) Convention, that is concerned with developing a strategy for protecting man and biota in the region of the north-east Atlantic, with an emphasis on the marine environment. The European Commission is providing input to the work of OSPAR though the results of a study – the Marina II study – part of which has recently produced a report that concluded that for selected industry-impacted locations in the OSPAR region, there is no identifiable impact on populations of marine biota from radioactive discharges.

Miscellaneous international activities

Canada, through its Department of Foreign Affairs, is a member of the Arctic Council (other members are the USA, Russia, Finland, Sweden, Norway, Denmark and Iceland). The IAEA, the United Nations Environment Program and the International Union of Radioecology (IUR) also participate. Recently, the Council has noted the need for the development of a protection framework that includes radioactive contaminants. Working closely with the IUR, the Arctic Monitoring and Assessment Program (AMAP) has the role of implementing the Council's protection strategy. The work of the AMAP is described on its website [www.amap.no].

The IUR is involved with most of the European programs noted above and it is noteworthy that an Asian branch of the IUR has been created to work on environmental protection in S. Korea, Japan and China. This is noteworthy because the members of the IUR are drawn from academia and the governmental authorities; although this initiative does not imply approval by the authorities, it does indicate an interest.

In an attempt to ensure that terms, quantities and units in radioecology are used precisely and clearly, the International Commission on Radiological Units and Measurements (ICRU) has produced a report that presents the primary quantities and terms that are used in studies of radionuclide transport in the environment and those used to help assess the effects of environmental radioactivity on plants, animals and humans [ICRU01]. To encourage greater uniformity and to minimize confusion in this field, both the currently recommended and previously used names and symbols are given. There is also a glossary of scientific terms that are often used in radioecology.

Summary

International agencies are currently very active in collating and interpreting the scientific knowledge on the effects of radiation on biota in the natural environment, in arriving at an agreed set of principles for protection, in resolving various technical issues, and in developing a framework for protection of the environment from ionizing radiation. In the next few years we can expect to see a new UNSCEAR report, new recommendations from the ICRP and a draft Safety Guide from the IAEA.

There will be opportunities for international collaboration between Canadian researchers and those in Europe through the ERICA program under the European Union, and with researchers from around the world through a proposed co-ordinated research program under the IAEA.

One can therefore expect that in the next few years there will be resolution of many of the issues currently being debated with a consensus developing on the principles, on the biological effects that are relevant, on reference fauna and flora, on dosimetry and reference organisms, on measurable endpoints and on the basic feature of a system of protection. This body of work will be available as a base, and as an harmonising influence, for national regulatory authorities around the world as they develop their own national regulations.

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Call for 2003 Nominations *Appel 2003 aux nominations*

Deadline for All Nominations: 2003 March 30 **Date limite pour toutes nominations: le 30 mars 2003**

W.B. LEWIS MEDAL / MEDAILLE W.B. LEWIS
IAN McRAE AWARD / PRIX IAN McRAE
OUTSTANDING CONTRIBUTION AWARD / LE PRIX D'EXCELLENCE
INNOVATIVE ACHIEVEMENT AWARD / LE PRIX EN INNOVATION
FELLOWS OF THE CANADIAN NUCLEAR SOCIETY / FELLOWS DE LA SOCIETE NUCLEAIRE CANADIENNE
JOHN S. HEWITT TEAM ACHIEVEMENT AWARD / LE PRIX JOHN S. HEWITT POUR REALISATION EN EQUIPE
CNS EDUCATION AND COMMUNICATION AWARD / LE PRIX SNC EN EDUCATION ET COMMUNICATION
R.E. JERVIS AWARD / LE PRIX R.E. JERVIS
SUBMISSION OF NOMINATIONS / SOUMISSION DES NOMINATIONS

Nominations for all of the above awards will be reviewed by the joint CNS/CNA Awards Committee. Please send your nominations in confidence, to reach the CNS office by 2003 March 30, to:

The Chair, Honours and Awards Committee
Canadian Nuclear Society
480 University Ave., Suite 200
Toronto, ON M5G 1V2

Except in the case of the R.E. Jervis Award, all nomination letters should bear three signatures. For the CNS Fellowship Award, the three signatures must be those of CNS members. In all cases a short biography of the candidate(s) should be included.
For further information, please consult the Honours & Awards page on the CNS website: (www.cns-snc.ca).

Les nominations pour tous les prix décrits ci-dessus seront étudiées par le comité conjoint SNC/ANC des prix. Veuillez envoyer vos nominations confidentiellement, à être reçues a la SNC au plus tard le 29 mars 2003, aux soins du:

Président du comité des prix et honneurs
Société Nucléaire Canadienne
480 avenue University, Suite 200
Toronto, ON M5G 1V2

Sauf dans le cas du prix R.E. Jervis, toutes les lettres de nomination doivent porter trois signatures. Dans le cas des nominations pour Fellow de la SNC, les trois signatures doivent etre celles de membres de la SNC. Dans tous les cas une courte biographic du candidat doit etre incluse.
Pour plus de details, veuillez consulter aussi voir la page des Prix et Honneurs au site internet de la SNC: (www.cns-snc.ca).

Waste Management Organization well underway

David Crombie

When the *Nuclear Fuel Waste Act* finally came into force on November 15, 2002, the **Nuclear Waste Management Organization** (NWMO) was already set up. On October 24 Richard Dicerni, executive vice president at Ontario Power Generation (OPG), announced the creation of the NWMO and the appointment of Elizabeth Dowdeswell as its president. *(See separate article.)*

The establishment of the NWMO by the nuclear utilities was stipulated in the Act. Its mandate is to investigate approaches for managing Canada's used nuclear fuel.

The Act, whose official title is *An Act Respecting the Long-Term Management of Nuclear Fuel Waste*, resulted from the Government of Canada's response to the report from the Nuclear Fuel Waste Management and Disposal Concept Environmental Assessment Panel, which was chaired by Mr. Blair Seaborn. That report was submitted in March, 1998 following 8 years of review.

The legislation was introduced for First Reading as Bill C-27 on April 25, 2001. Following extensive reviews by committees of the House of Commons and the Senate, the legislation received Royal Assent on June 13, 2002.

The Nuclear Fuel Waste Act requires electricity generating companies which produce used nuclear fuel (OPG, NB Power, Hydro Quebec) to:

- establish a waste management organization to provide recommendations on the long-term management of used nuclear fuel to the Government of Canada, and,
- establish segregated trust funds to finance the long term management of the used fuel.

The Act also requires the waste management organization to establish an Advisory Council whose comments on the waste management organization's study and reports will be made public.

Among the first activities for the organization will be a study of long-term management approaches for used nuclear fuel, including the design of an innovative and wide-ranging program of public consultation. *As noted in the interview with Elizabeth Dowdeswell, initial steps have already been taken.)*

Within three years the NWMO must submit to the Minister of Natural Resources its proposed approaches for the management of used nuclear fuel, along with comments of the Advisory Council. It must also identify its preferred approach. Then it will be the responsibility of the Governor in Council (Cabinet) to decide on the approach to be followed. Once that choice has been made the Nuclear Waste Management Organization will have the task of seeing that it is implemented, subject to all of the applicable regulatory approvals.

The required Trust Fund was established on November 25, 2002 with the contributions stipulated, i.e.,

- Ontario Power Generation $500,000,000.
- Hydro Quebec and New Brunswick Power each $20,000,000
- Atomic Energy of Canada Limited $10,000,000

Each year the named organizations must contribute a further amount:

- Ontario Power Generation $100,000,000
- Hydro Quebec and New Brunswick Power each $4,000,000
- Atomic Energy of Canada Limited $2,000,000

The Trust Fund is to cover the cost of implementing whatever approach is eventually decided upon.

Board of Directors

The initial members of the Board of Directors are:

Richard Dicerni (Chair)	Ontario Power Generation
Ken Nash (Vice-Chair)	OPG
Rene Pageau,	Hydro Quebec
Stuart Groom,	NB Power
Adele Malo,	OPG
Fred Long,	OPG

Advisory Council

As noted above the Act requires the NWMO to establish an advisory council. which is to review and comment on the work of the organization. Further, the Act states that reports from the Advisory Council must be made public.

The Advisory Council has been established and, at the time of writing, already has had two meetings.

The chair of the Advisory Council is David Crombie, President and CEO of the Canadian Urban Institute. A past mayor for the City of Toronto and former Member of Parliament and Cabinet Minister, he has served on and chaired several high profile panels and commissions. Mr. Crombie was the first Chancellor of Ryerson Polytechnic University and is the recipient of honorary doctorates of law from the Universities of Toronto and Waterloo.

The other members are:

David Cameron,	Professor of Political Science at the University of Toronto
Helen Cooper,	former mayor of Kingston, community worker
Gordon Cressy,	Vice President of Ryerson University
Frederick Gilbert,	President of Lakehead University
Dr. Derek Lister,	holds Chair in Nuclear Engineering, University of New Brunswick
Donald Obonsawin,	former Deputy Minister of several Ontario Ministries
Daniel Rozon,	Department Head, Engineering Physics at Ecole Polytechnique de Montréal

A Conversation with Elizabeth Dowdeswell

On January 23, 2003, Elizabeth Dowdeswell, the recently appointed president of the Nuclear Waste Management Organization, met the editor of the CNS Bulletin. Following is a summary of that conversation. See the sidebar for an outline of Ms. Dowdeswell's background.


Elizabeth Dowdeswell

Q. Ms. Dowdeswell, you have had an illustrious career but none of your previous positions were even remotely connected with an organization such as NWMO. Why did you take the job?

A. It was not something I was looking to do but I soon saw it as an exciting challenge. It involves an essential policy issue of how to balance benefits and costs. I acknowledge that many people have fears [about nuclear waste]. I understand the public response issue, having spent much of my life in public service involving many forms of public engagement. This is a real problem in search of a solution. The challenge will be to try to develop a policy built not just on science but also on social and ethical values, that is to take a holistic approach.

Q. Where are you in the program?

A. The organization has been set up as a non-profit corporation with a Board of Directors of six members chaired by Richard Dicerni [VP of Ontario Power Generation]. An Advisory Council has been established and has met three times. Administratively we have located offices and are in the process of recruiting staff and becoming operational.

I have already had a number of discussions with key stakeholders [including CNS] and these will continue with many others such as residents of communities near nuclear power plants, parliamentarians, municipal officials, NGOs, etc. to identify their expectations. My first months will be spent primarily listening. There is no master plan carved in stone. We cannot have a real dialogue without understanding what the concerns are. Only when we understand those concerns and identify the fundamental questions, can we turn to proposing specific options. Our mandate is to recommend a management approach.

I hope to develop a process that is seen as fair and transparent. In the end I want to be able to go to the government with a recommendation which it will have confidence in and that it can enact. To that end I intend to try a number of different methods to reach people unlike a typical environmental assessment panel. This can include community roundtables, public opinion research, scenario building exercises, and other methods.

Q. The Act specifically mentions three approaches. Do you consider that you could recommend some combination or alternative?

A. We must look at the three approaches specified in the Act but my understanding is that we can consider other methods and possibly combinations.

We must do the technical studies such that people feel that all options have been explored. After ten years we know a great deal about one option, deep geological disposal. I intend to ensure that there is a genuine exploration of all [feasible] options, taking in all factors, technical, economic, social and environmental.

Q. Where are you in engaging staff?

A. We plan to have only a relatively small core of people. That core group must be able to manage other consultants and groups. Some staff will be seconded from the nuclear utilities but we have also been speaking to social science and technical experts from other industries, government and civil society. We also hope to have an international group of advisors. We may be advertising but a number of people have already been knocking on our door. The overall time frame is very short.

Q. You mentioned that an Advisory Council has already been set up. Could you comment further ?

A. Yes, the Advisory Council was created very early and includes some very impressive people. *(See sidebar.)* The Council has already met three times and has a full agenda to gain understanding about the nuclear industry and waste management, to review international developments and past developments in Canada. We will be relying on the Advisory Council throughout the process, not just at the time of the required reports. We have asked the Council to challenge us every step of the way.

Q. During the Seaborn hearings representatives of first nations were very critical. Will you be dealing with this issue?

A. The Act specifically calls for special attention to the views of First Nations and we will be developing a consultation strategy in concert with them.

Q. You are required to submit annual reports. When will you do the first one?

A. We must submit a report covering the 2002 fiscal year even though we have been operating only since late fall. This will be delivered by the end of March.

Elizabeth Dowdeswell

Elizabeth Dowdeswell hails from Saskatchewan and attended the University of Saskatchewan where she obtained a Bachelor of Science degree in home economics and a teaching certificate. She continued her studies at the Utah State University from which she holds a Master of Science degree in behavioural sciences.

After a number of years as a high school teacher, a university lecturer, educational consultant with the Saskatchewan Department of Education, and a human rights ombudsman she was appointed Deputy Minister of Culture and Youth for the Province of Saskatchewan. In that post she directed a major public review of cultural policy and developed heritage legislation.

Moving to the federal scene, Ms. Dowdeswell was the Assistant Deputy Minister of Environment Canada, from 1989 to 1992, where she was responsible for the national weather and atmospheric agency. In that capacity she played a leading role in global efforts to negotiate the treaty on climate change adopted at the 1992 United Nations Conference on Environment and Development. She was also Canada's permanent representative to the World Meteorological Organization; principal delegate to the Intergovernmental Panel on Climate Change; and Canadian Chair of the Great Lakes Water Quality Board.

From 1993 to 1998 she served as Executive Director of the United Nations Environment Program, where she led the agency's transformation into a modern organization, developing programs in state-of-the-environment assessment and reporting, environmental law, and tackling new issues of trade and globalization.

Most recently, Ms. Dowdeswell's professional activities have included: management consulting; Visiting Professor in Global Health, Genomics and Ethics at the University of Toronto; Commissioner of the Commission on Globalization; and Associate Fellow of the European Centre for Public Affairs.

She is the author of numerous publications in both popular press and professional journals and has received nine honorary degrees including six Doctor of Law degrees from various universities, a Doctor of Humane Letters degree from Mount Saint Vincent University in Halifax and the Memorial Gold Medal awarded by Charles University in Prague.

Radioactive Waste Management At AECL

by R.D. Gadsby & C.J. Allan[1]

Ed. Note: *The following paper was first presented at the PBNC 2002 conference in Shenzhen, China, October 2002.*

Abstract

AECL has maintained an active program in radioactive waste management since 1945, when the Canadian nuclear program commenced activities at the Chalk River Laboratories (CRL). Waste management activities have included operation of waste management storage and processing facilities at AECL's CRL and Whiteshell Laboratories (WL); operation of the Low Level Radioactive Waste Management Office on behalf of Natural Resources Canada to resolve historic radioactive waste problems (largely associated with radioactive ore recovery, transport and processing operations) that are the responsibility of the Federal Government; development of the concept and related technology for geological disposal of Canada's nuclear fuel waste; development of the Intrusion-Resistant Underground Structure (IRUS) disposal concept for low-level nuclear waste; development of dry storage technology for the interim storage of used fuel; and development and assessment of waste processing technology for application in CANDU nuclear power plants and at CRL and WL.

Today these activities are continuing. In addition, AECL is:

- preparing to decommission the nuclear facilities at WL;
- carrying out a number of smaller decommissioning projects at CRL;
- putting in place projects to upgrade the low-level liquid waste processing capabilities of the CRL Waste Treatment Centre, recover and process highly active liquid wastes currently in storage, and recover, condition and improve the storage of selected fuel wastes currently stored in below-ground standpipes in the CRL waste management areas; and
- assessing options for additional remediation projects to improve the management of other wastes currently in storage and to address environmental contamination from past practices.

1. Introduction

AECL, as the Federal Crown Corporation charged with leading the development of peaceful applications of nuclear technology in Canada, has a long history of managing radioactive wastes, beginning with the establishment of the Chalk River Laboratories (CRL) in the mid-forties. In fact, the first radioactive waste management area at the Chalk River site, a landfill, received its first waste in 1947. Even before the startup of CRL, Canada was already involved in the mining and processing of radium and then uranium ores, and these activities have left a legacy of radioactive wastes.

Radioactive wastes encompass a wide spectrum of characteristics - including physical, chemical and radiological properties. It is well recognised that radioactive waste management needs to be planned and implemented as a continuum of integrated activities that take account of the various steps in waste management (see Figures 1, 2). Thus, wastes need to be segregated and characterized; so that they can be processed, packaged, stored, and eventually disposed of in an optimum manner - i.e. constraining costs while meeting the fundamental objectives of protecting worker safety, protecting public health, and protecting the environment, now and in the future, while at the same time minimizing the burden passed to future generations.

2. Waste Management and Decommissioning at AECL Laboratories

In the early days of radioactive waste management at AECL laboratories, the radiological hazards posed by radioactive wastes were well recognised - e.g., solid wastes were managed in segregated waste management areas. But, for many years, the wastes were largely characterized and managed on the basis of external radiation fields to ensure the radiation protection of workers while constraining costs. Thus, at CRL, very low activity liquids were directly discharged to the Ottawa River with appropriate monitoring to ensure releases

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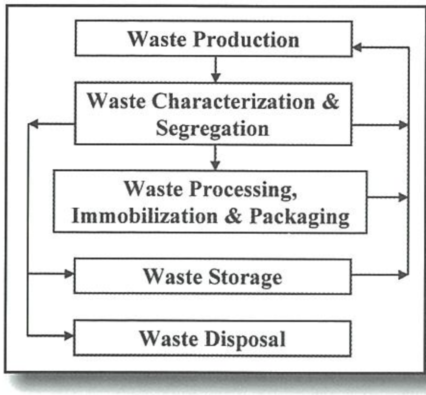

Figure 1. Steps in Radioactive Waste Management

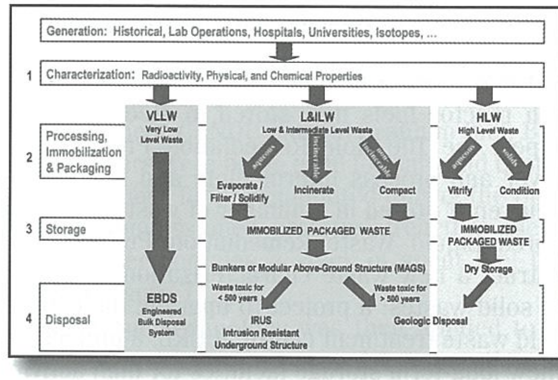

Figure 2. AECL Waste Management Strategy

were well below regulatory limits, typically <1%. Higher activity, large-volume liquid wastes were discharged to gravel-filled dispersal pits built into sand overburden in designated waste management areas. Still higher activity liquid wastes were processed to remove radioactive contamination, using techniques such as ion exchange, reverse osmosis, micro-filtration and evaporation. The highest activity liquid wastes arising from the processing of fuels were placed into storage in shielded tanks.

Similarly, very low activity solid wastes were placed into sand-trench landfills; higher activity, but contact-handleable wastes were placed in lined trenches and concrete bunkers; and used reactor fuel and other highly active wastes were placed into standpipes below ground, where shielding is provided by the soil surrounding the standpipes and the transfer of wastes from shipping flasks into the standpipes is relatively straight-forward (see Figures 3, 4)

Over time these waste management practices have evolved as knowledge and technology have improved. Thus, at AECL's Whiteshell Laboratories (WL), contact-handleable wastes have been stored in above-ground storage facilities for many years, and this practice has recently been adopted at CRL for solid wastes previously placed into a landfill. The use of dispersal pits for liquids has been discontinued at CRL and low-level liquid wastes are now processed in an upgraded liquid waste treatment centre. At WL, above-ground dry storage technology has been used for the storage of research reactor and other fuels since the mid-70s, but the use of standpipe technology is still used at CRL for high-activity wastes. The intention, however, is to phase out this practice over the next several years.

Recently, a comprehensive 10-year waste management plan has been produced for the CRL site that identifies the remaining gaps between current practices and best practices worldwide, and that defines the steps to be taken to close the gaps. Project teams are being established within a project management group dedicated to waste management remediation and enhancement projects. The waste management remediation projects are being carried out to address legacy liabilities that have arisen from past waste management practices.

Figure 3. High-activity waste being transferred from a shipping flask into standpipe storage. Adjacent standpipes are covered with resusable shielding plugs.

Figure 4. Standpipes for storage of high activity wastes during construction. The standpipes are surrounded by sand to provide support and shielding.

The suite of waste remediation and waste enhancement projects include the following: a project to recover, condition and place into a new interim storage facility, historic research reactor fuels now stored in steel-lined concrete standpipes, the Tile Hole Remediation Project; a project to recover and process intermediate and high-level liquid waste currently stored in a number of waste storage tanks, the Stored Liquid Waste Remediation Project; a project to construct a new waste characterization facility for low activity solid wastes; a project to upgrade the capability of the liquid waste treatment centre at CRL; a project to put in place new long-term storage facilities for high activity solid wastes to phase out the use of standpipes; and completion of the "IRUS" (Intrusion-Resistant Underground Structure) project to establish Canada's first licensed disposal facility for short-lived radioactive wastes.

3. Low-Level Radioactive Waste Management Office

The Low-Level Radioactive Waste Management Office (LLRWMO) is a project group operated by AECL through a cost-recovery agreement with Natural Resources Canada, to address non-AECL historic radioactive waste management liabilities that are the responsibility of the Government of Canada. The LLRWMO was established in 1982 as a small dedicated project management organization, separately funded and staffed by AECL with technical and management professionals overseeing projects and their related expenditures. The LLRWMO performs work with its own core staff, or oversees work led by consultants in the areas of waste site characterization, development of clean-up criteria, and engineering and supervision of clean-up and remedial work. It also constructs and operates interim storage facilities for historic low-level radioactive waste and operates ongoing programs to assist communities to co-exist with low-level radioactive waste and contaminated land. To fulfill its mandate, the LLRWMO works with communities and regulatory agencies to clean up and manage waste on an interim basis and to develop acceptable long-term waste management solutions.

The LLRWMO and its predecessor, the Federal-Provincial Task Force on Radioactivity, have surveyed over 7,000 properties and structures for historic low-level radioactive waste contamination and have cleaned up homes, residential properties, commercial properties, wooded areas, public parks and roadways in various Canadian communities. The LLRWMO has also built interim storage and management facilities. About 500 sites have been cleaned up, ranging from private residential properties and municipal buildings in urban areas to parkland in suburban communities and remote sites along historic transportation routes for uranium ores.

For example, in the Scarborough area of Toronto, Ontario, 68 occupied residential properties and three vacant sites have been remediated (see Figure 5). About 16,600 cubic metres of radium-contaminated soil was excavated and processed using a custom-built mechanical sorting and segregation system. Of this amount, about 50 cubic metres of licensable material was transferred to the packaged waste warehouse facilities operated for the LLRWMO at CRL (see Figure 6). About 9,000 cubic metres was placed in a local purpose-built temporary storage area and is regularly monitored. Through the process of sorting and segregation, it was determined that over 7,000 cubic metres of material did not require special handling.

In Port Hope, Ontario, the LLRWMO has been active since 1982 in remediation activities, the search for disposal opportunities and the interim management of low-level radioactive waste and contaminated sites. In 2001 June, the LLRWMO was designated by the Government of Canada to act as "proponent" to begin the complete environmental clean-up of low-level radioactive waste in the Port Hope area. This project will involve an environmental assessment and licensing, construction and management of three new long-term waste management facilities for about 1.5 million cubic metres of contaminated material, and final remediation of hundreds of land parcels. This new initiative, which will require 10 years to complete, follows previously unsuccessful attempts by the federal government and others to establish disposal or storage

Figure 5. Contaminated Soil Activities at Malvern (Scarborough, Ontario)

Figure 6. Packaged Waste Storage at LLRWMO Warehouse, CRL

facilities enabling the final clean-up and relocation of the historic low-level radioactive wastes. The recent success is attributed to host community-proposed concepts to establish storage facilities within their own boundaries, which culminated in a legal agreement between three municipalities and the federal government in 2001 March for the safe long-term management of the waste.

4. Used Fuel Management

The Canadian strategy for managing the used fuel from Canada's CANDU ® nuclear power plants has been to provide safe interim storage at the reactor sites using a combination of pool and dry storage technology, and in parallel to develop the technology for disposal. Both pool and dry storage of spent fuel are fully proven, based on many years of successful, safe operating experience. In addition, AECL's extensive R&D program on the permanent disposal of spent fuel has resulted in a defined concept for Canadian fuel disposal in plutonic rock of the Canadian Shield.

5. Interim Storage of Spent Fuel

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

After spent CANDU fuel has been out of the reactor for about six years, its activity and rate of heat generation have decreased sufficiently to allow the fuel to be transferred to dry storage, if desired. Compared with wet storage, dry storage is considered to have the following advantages: passive and inherently safe storage mode; less potential for contamination of the storage facility; little or no corrosion of fuel sheaths; less radiation exposure to operating personnel; minimal maintenance; low operating costs; simplicity; and ability to add modules as required.

AECL started to study dry storage for spent nuclear fuel in the early 1970s. Silo-like structures called concrete canisters were first developed for the storage of enriched uranium fuel from research reactors and were then further developed for spent CANDU natural uranium fuel. By 1987, concrete canisters were being used for safe and economical storage of all spent fuel accumulated during the operation of AECL's decommissioned prototype reactors (see Table 1). Each canister contains a stack of spent fuel baskets, illustrated in Figure 7.

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

In 1989, AECL began development of a monolithic, air-cooled concrete structure for dry storage, called MACSTOR (see Figures 8, 9). MACSTOR modules require less land area than concrete canisters for the same amount of spent fuel and are suitable for storage of spent fuel assemblies from other reactor types (PWR, BWR, VVER) as well as CANDU reactors.

In 1995, Hydro-Québec built the first such system for dry storage at the Gentilly-2 CANDU 6 nuclear generating station. In 2000, the Romanian company Societatea Nationala Nuclearelectrica S.A. (SNN), the plant owner of the Cernavoda station, proceeded with an international bid for the supply of dry storage technology for spent fuel from Unit 1 (and eventually Unit 2) of the Cernavoda CANDU 6 nuclear power plant. The MACSTOR system emerged as the most suitable technology and AECL is supplying the complete spent fuel packaging system and dry storage structure, including the construction of one storage module. The project started in 2001 and is on schedule for the planned construction of a MACSTOR module during the second half of 2002, with fuel loading in 2003.

Since 2001, KHNP/NETEC (Korea) and AECL have been developing a higher-capacity dry storage structure based on the MACSTOR concept, for the Wolsong site. The selected configuration is a 4-row MACSTOR-like module with a capacity of 24,000 bundles stored in 400 baskets,

TABLE 1: CANDU Spent Fuel Currently In Dry Storage

Location	Fuel	Number of Canisters
Whiteshell Laboratories	17 MgU	11
Gentilly-1	67 MgU	11
Douglas Point	298 MgU	47
Nuclear Power Demonstration	75 MgU	11
Pt. Lepreau	2790 MgU (lifetime)	275 (lifetime)
Wolsong-1	2790 MgU (lifetime)	275 (lifetime)
Gentilly-2	2790 MgU (lifetime)	275 (lifetime)

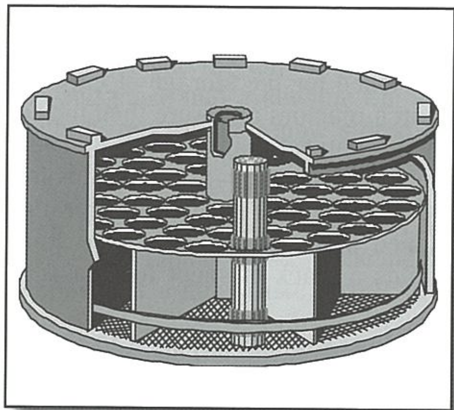

Figure 7. Basket Holding 60 CANDU Spent Fuel Bundles

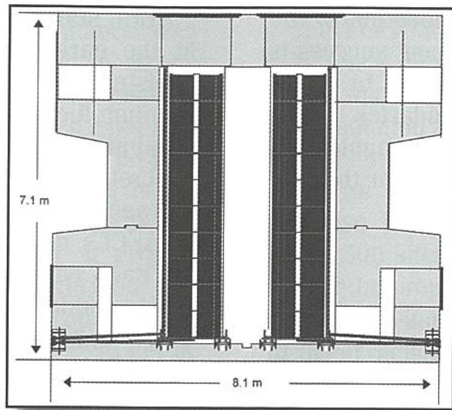

Figure 8. MACSTOR Dry Storage Module – Gentilly 2

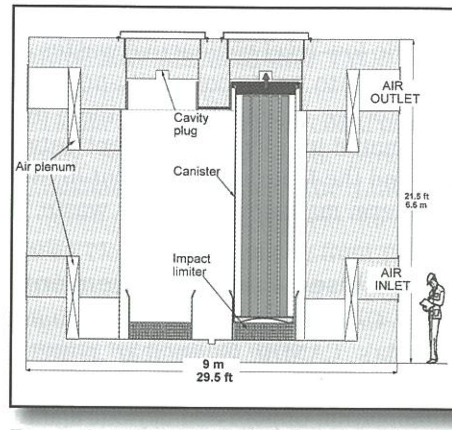

Figure 9. MACSTOR Dry Storage Module – LWR Configuration

each holding 60 spent fuel bundles. The module design (MACSTOR/KN-400) is expected to offer a repetitive storage density increase by a factor of about 3, compared to concrete canisters that are presently in use .

6. Disposal of CANDU Nuclear Fuel Waste

Current storage practices have an excellent safety record at CANDU sites, permit easy monitoring and retrieval, and could be continued for many years. But storage, while an extremely effective interim measure, is not considered to be a permanent measure. Canada and other countries with nuclear power programs have for many years been developing the technology for the permanent disposal of nuclear fuel waste. There is international consensus among waste management experts that the preferred method for long-term management of nuclear fuel waste is land-based geological disposal.

The objective of permanent disposal is to manage nuclear fuel waste in such a way that security, monitoring and maintenance are not required, even in the long term. This does not mean that society would not use long-term institutional controls as a management tool, but rather that, even if such controls should fail, human health and the natural environment would still be protected. In addition, even though human intervention, such as retrieval of waste packages, is not intended, it would not be precluded.

Land-based geological disposal would involve placing containers of waste in sediment or rock hundreds of metres deep, with access from the land surface. The main advantages of land-based geological disposal are that most nations have within their borders rock types potentially suitable for disposal facilities, and land-based disposal concepts can be based on existing mining and engineering technology. Research has concentrated on disposal media (rock types) having one or more of the characteristics commonly considered favourable for disposal. The decision to focus on a particular rock type or types is made in each country on the basis of the geological conditions within that country and a variety of other relevant factors. International research on land-based geological disposal of radioactive waste has concentrated on five disposal media: plutonic rock (often referred to as crystalline rock), salt, clay (or shale), tuff and basalt.

The AECL concept for disposal of Canada's nuclear fuel waste is based on deep geological disposal in the rock of the very stable Canadian Shield. In common with the approach adopted in other countries, the disposal concept developed by AECL entails isolating the waste from the biosphere by a series of engineered and natural barriers .

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

Several countries 6-16 including Canada 4, 17 have carried out quantitative assessments of the risk associated with disposal. These analyses indicate that the amount of contaminants moving from a repository to the surface would be very small and that the radiological dose would be many orders of magnitude below that from naturally occurring radioactivity in the surface environment, and even further below that known to cause harm.

The concept for the disposal of Canada's nuclear fuel waste underwent an extensive environmental review by an independent panel under the Government of Canada's

Environmental Assessment and Review Process. In its report, the panel concluded that from a technical perspective, the safety of the AECL concept has been adequately demonstrated for the stage of development; but from a social perspective, that there was not currently broad public support demonstrated for the concept.

In response to the panel's report and recommendation, the Government of Canada has introduced legislation 19 , directing the Canadian utilities operating commercial nucle-

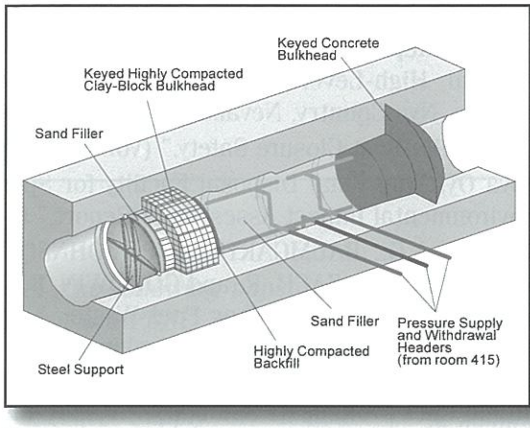

Figure 10. Configuration of the Tunnel Sealing Experiment

ar reactors to establish a Waste Management Organization (WMO) to study options for the long-term management of nuclear fuel waste, including geological disposal based on the concept developed by AECL, storage at reactor sites and centralized storage, and to recommend a preferred option to the government.

Pending the formation of the WMO, Ontario Power Generation (OPG) has continued to provide technical direction and financial support to advance and optimize the disposal technology and to maintain key areas of technical expertise. Over the past several years,

AECL has worked in collaboration with OPG to identify the technical work scope and to perform the R&D required to further develop technology for deep geological disposal, in the areas of geoscience and methods for site characterization, repository design and engineering, and long-term safety assessment.

7. International Collaboration and the IAEA

At its Underground Research Laboratory (URL) in Manitoba, AECL has conducted research and demonstration projects in collaboration with the waste management organizations in a number of other countries, including Finland, France, Japan, Sweden, United Kingdom and the United States. A recent achievement was the completion of the first phase of the Tunnel Sealing Experiment (TSX), co-sponsored by AECL, OPG, ANDRA of France, JNC of Japan and the US-DOE 20 . The TSX is a large-scale demonstration of the design, construction and performance of concrete- and clay-based seals similar to those that would be used in a geological repository. Two bulkheads, one composed of high-performance concrete and the other of highly compacted sand-bentonite material, have been constructed in a tunnel in unfractured granitic rock at the URL (see Figure 10). The results from the TSX have been used to characterize the performance of the two bulkheads under applied hydraulic pressures.

The chamber between the two bulkheads has been pressurized to 4 MPa, a value representative of the ambient pore pressures in the rock at a depth of 420 m. Instrumentation in the experiment monitors the seepage through and around each bulkhead, as well as parameters that are important indicators of bulkhead performance. In the recently initiated second phase of the TSX, the performance of the two bulkheads will be tested at higher temperatures, comparable to those expected in a geological repository.

AECL's URL is dedicated to the study of technologies related to the long-term management and deep geological disposal and storage of nuclear fuel waste. For over 10 years, a major experimental program has been undertaken in the URL to study and develop various facets of the technologies that form the basis of the disposal concept for Canada's spent nuclear fuel.

In June of 2000, the Canadian government announced an initiative to work with the IAEA in the development of an International Training and Demonstration Facility for nuclear fuel waste management and disposal technologies, based at AECL's URL. The IAEA has emphasized the importance of addressing the challenges posed by the long-term management and disposal of spent nuclear fuel and high-level radioactive waste, particularly in view of the influence this issue has on public perception and acceptance of nuclear energy.

There is wide international interest in developing expertise and hands-on experience in an underground laboratory environment, particularly among IAEA member states that do not have their own URLs. Such arrangements are also viewed as being of mutual benefit by countries with existing URLs.

Other countries have now offered the use of their underground facilities to support the IAEA objectives, e.g., Belgium, Switzerland, the US, resulting in the formation of an IAEA

AECL has been managing radioactive wastes for over 50 years – and has acquired substantial expertise, capabilities and technologies that can now benefit international clients, while AECL continues to manage Canada's nuclear legacy.

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The Maple Reactor Project

by G. R. Malkoske[1] and J.-P. Labrie[2]

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Abstract

MDS Nordion supplies the majority of the world's reactor-produced medical isotopes. These isotopes are currently produced in the NRU reactor at AECL's Chalk River Laboratories (CRL). Medical isotopes and related technology are relied upon around the world to prevent, diagnose and treat disease. The NRU reactor, which has played a key role in supplying medical isotopes to date, has been in operation for over 40 years. Replacing this aging reactor has been a priority for MDS Nordion to assure the global nuclear medicine community that Canada will continue to be a dependable supplier of medical isotopes.

MDS Nordion contracted AECL to construct two MAPLE reactors dedicated to the production of medical isotopes. The MDS Nordion Medical Isotope Reactor (MMIR) project started in September 1996. This paper describes the MAPLE reactors that AECL has built at its CRL site, and will operate for MDS Nordion.

1. Maintaining an Essential Source of Global Supply

This paper describes the role of MDS Nordion and AECL in providing a secure global supply of medical isotopes. The first part of the paper discusses the uses of medical isotopes, their importance to the medical community, and the benefits to patients of a secure supply of medical isotopes. The second part describes the new MAPLE reactors being commissioned at AECL's Chalk River Laboratories to meet the world market demand for medical isotopes for the next 40 years.

MDS Nordion is the world's leading supplier of medical isotopes. The company is in the business of supplying isotopes used to conduct some 34,000 nuclear medicine procedures performed every day around the world, such as determining the severity of heart disease, the spread of cancer, and diagnosing brain disorders.

There are currently more than 100 medical applications for radioisotopes, with 80% of nuclear medicine procedures relying on just one isotope, molybdenum-99. Some of these procedures are performed using medical isotopes that have left the reactor only 41 hours earlier. This is truly a just-in-time business and a global endeavour. As the radioisotope decays, MDS Nordion must deliver the product to the customer as quickly as possible.

Moreover, 5000 hospitals in North America depend on this supply each week. Other examples of hospitals around the world that rely on the supply of medical isotopes currently produced at AECL's NRU reactor include 850 hospitals in Germany, more than 1000 hospitals in Japan, and 250 hospitals in Argentina.

MDS Nordion's medical isotope business is also creating exciting new applications in radioimmunotherapy. Today, molybdenum-99 is the most extensively used isotope.

However, new medical techniques are providing opportunities for iodine-131, and iodine-125 and xenon-133 usage is also growing. For example, novel ways of using radioisotopes are being developed to treat diseases such as non-Hodgkin's lymphoma, a blood-borne cancer. These developments will expand the horizon for applications of medical isotopes.

The NRU reactor owned by AECL at Chalk River has operated since 1957 and has been producing molybdenum since the early 1970's. Today the NRU also supplies other medical isotopes, including cobalt-60.

In 1996, MDS Nordion and AECL responded to the concerns of the nuclear medicine community about the long-term, secure supply of molybdenum-99, and announced an agreement that will ensure a reliable and economic supply of radioisotopes to hospitals and clinics worldwide.

The agreement provided for the construction of two MAPLE reactors and a high-volume, commercial, first-stage processing facility at AECL's Chalk River Laboratories. MDS Nordion will own the reactors and processing facility, and be responsible for managing the business and planning activities of isotope production. AECL has been contracted to design, build, and operate the facilities on behalf of MDS Nordion.

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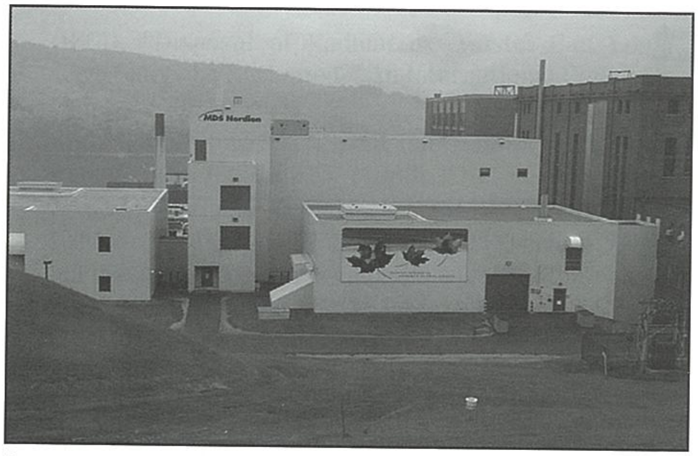

Figure 1: MAPLE reactors and isotope processing facility

The MAPLE reactors will be the only reactors in the world totally dedicated to the commercial production of medical radioisotopes. MDS Nordion's significant investment in the AECL site at Chalk River will capitalize on the extensive infrastructure, expertise and experience of AECL for the reliable, continuous production and supply of medical isotopes.

2. The MDS Nordion Medical Isotope Reactor (MMIR) Project

In August 1996, MDS Nordion contracted AECL to build two MAPLE reactors and an associated isotope processing facility at AECL's Chalk River Laboratories. The MMIR Project started in September 1996. The objectives of the project were to design, build, and commission two identical 10 MW MAPLE reactors and a processing facility that would start commercial production of medical isotopes in calendar year 2001.

The environmental assessment for the project was approved in April 1997, construction approvals were granted in December 1997, and all construction work was completed in 29 months by May 2000. Figure 1 shows the MAPLE reactor and the isotope processing facility buildings (these are the buildings with beige siding). The photograph also shows the NRU reactor in the background and the NRX reactor, which was shut down in 1992, to the right in the photograph.

Operating licences for the MAPLE 1 reactor and the processing facility were granted in August 1999. The licence was amended in June 2000 to include the MAPLE 2 reactor. Commissioning of the facility systems started in June 1999 and overlapped the construction phase. The MAPLE 1 reactor achieved its first sustained chain reaction in February 2000, just 41 months after the start of the project.

Active commissioning of the facilities has been on hold since July 2000 after problems were encountered during testing of the MAPLE 1 shut-off rod operation. Investigation into the root cause of the problems identified some workmanship issues in the construction of the facilities that had not been captured by the quality management system in place during construction.

This led to the detailed re-inspection of all MAPLE reactor and processing facility systems. Since July 2000, activities have been underway to correct the problems with the operation of the shut-off rods, and to address the workmanship issues that were identified. These activities are nearing completion. At no time was there any impact on safety to workers, the public or the environment.

Commercial production of medical isotopes in the new facilities is now scheduled for 2003, more than two years later than the original project objective.

3. The MAPLE Reactors

Figure 2 shows a cross section of the MAPLE reactors. The reactors are open pool-type reactors, each with a thermal power of 10 MW, designed for the sole purpose of producing medical isotopes.

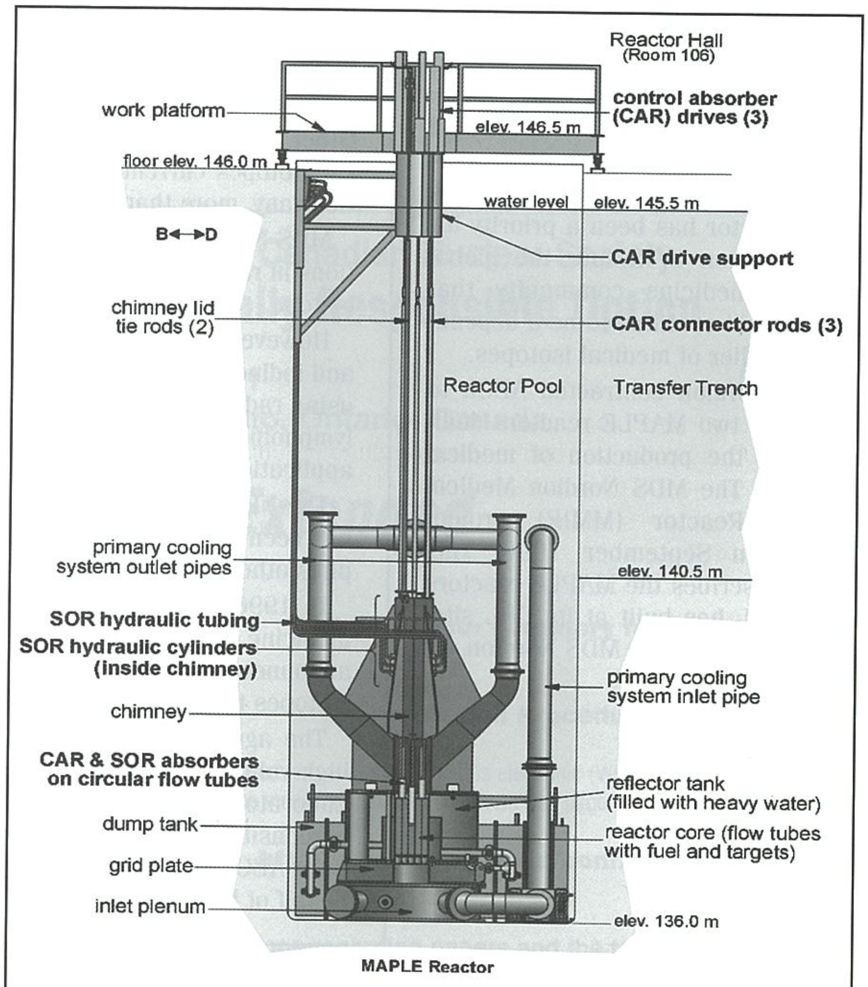

Fig. 2: MAPLE Reactors (SOR = Shut-off Rod, CAR = Control Absorber Rod)

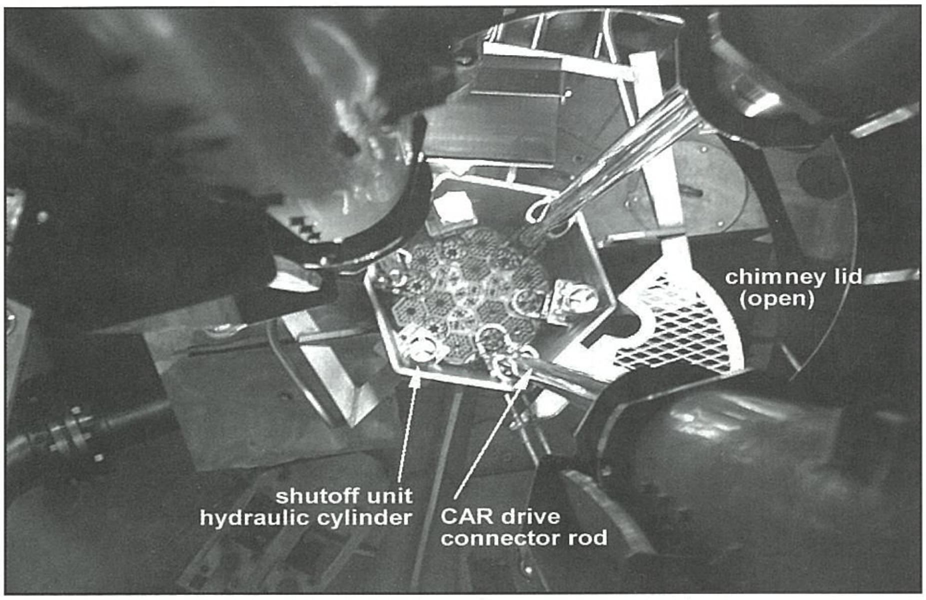

Figure 3: MAPLE Reactor Core (CAR = Control Absorber Rod)

The reactors are fuelled with Low-Enriched Uranium (LEU) silicide fuel dispersed in an aluminium matrix. The fuel is manufactured by AECL. The reactors are licensed to irradiate Highly Enriched Uranium (HEU) targets in their core to produce the following medical isotopes as fission products of uranium-235: molybdenum-99, iodine-131 and xenon-133.

Fuelling and target removal operations are performed manually from the top of the reactor pool with the reactor shut down. The reactor core, which measures about 400 mm in diameter and 600 mm in height, is near the bottom of a 10 m deep pool.

Figure 3 shows the MAPLE reactor core during low-power commissioning. The core has 19 fuel sites, consisting of 13 hexagonal and 6 circular sites. Nine hexagonal sites contain 36- element LEU fuel bundles, and the remaining four contain HEU isotope production targets.

The six circular sites contain 18-element fuel bundles. A heavy water reflector surrounds the core and contains irradiation sites for the production of iodine-125.

Each MAPLE reactor core, including the LEU driver fuel and HEU targets, contains a nominal uranium-235 content of about 5 kg. The LEU fuel is aluminium that contains 61% (weight) uranium-silicide. The uranium is enriched with 19.75% (weight) uranium-235. Each fuel element contains an 11.85 g uranium-235cylindrical core, 6.35 mm in diameter by 600 mm in length, in an aluminium cladding surrounded by eight cooling fins at 45 ° intervals.

The HEU targets each contain 18.5 g of uranium-235 in the form of uranium dioxide with 93% (weight) uranium-235. The targets are a thin annulus of uranium dioxide crush-compressed between two concentric zircaloy tubes. The nominal dimensions of the targets are 15.2 mm OD, 13.2 mm ID, and 482.6 mm length. The average linear power is 32 kW/m for fuel elements and 140 kW/m for targets. Figures 4 a) through 4 c) show the peak thermal neutron flux distribution in the reactors and the typical axial profile, based on measurements at 1 kW and normalized to 10.252 MW.

The reactor core is cooled by forced water flow. Water, circulated by the primary cooling pump, enters the inlet plenum (see Fig. 2) and flows vertically upward through flow tubes that contain fuel or targets. The water exits from the flow tubes into the chimney, where it mixes with a descending flow of pool water. The combined flow leaves the chimney through two outlets and then returns to the suction side of the pump. The pump directs the flow through a heat exchanger, where heat is rejected to the process water system. The total water flow through the core is 320 kg/s, and the maximum outlet pump pressure is 705 kPa (g). The core inlet water temperature is 30 °C, and the core outlet temperature is 37 °C.

Each MAPLE reactor has two independent and diverse safety systems. (See Figures 2 and 3.):

- Safety System 1 - has three hydraulically actuated shut-off rods.
- Safety System 2 - has three electromagnet actuated control absorber rods and a hydraulically actuated reflector dump system.

Any two of the three shut-off rods that are dropped into the core will place the reactor in a stable sub-critical state. Similarly, any two of the three control absorber rods that are dropped into the core will place the reactor in a stable sub-critical state. The reflector dump system will also place the reactor in a stable sub-critical state.

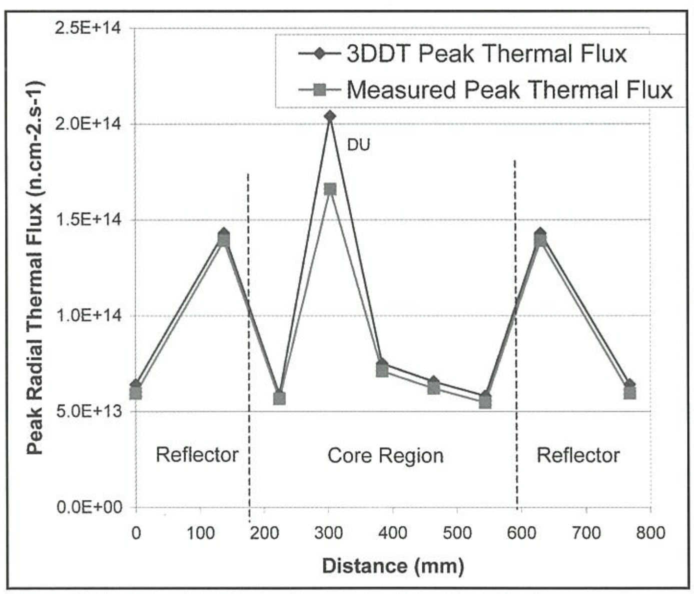

Fig. 4a) Peak radial thermal neutron flux distribution

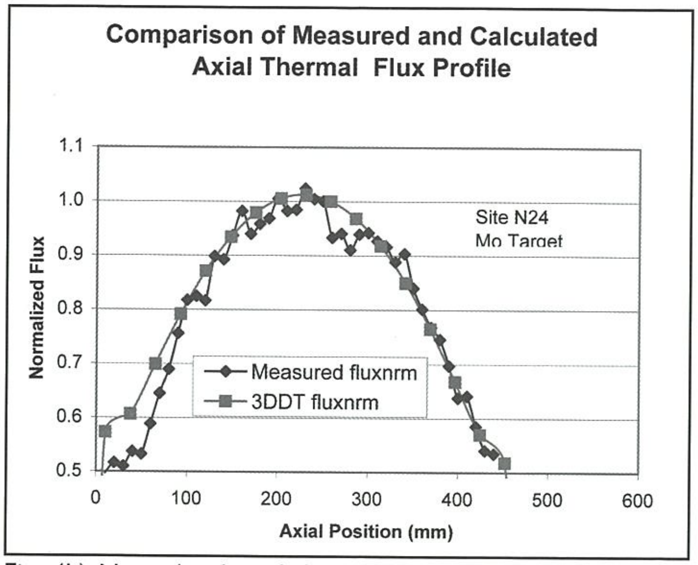

Fig. 4b) Normalized axial thermal neutron flux distribution at target site 6

During operation, the three shut-off rods are held out of the core by their hydraulic systems.

The control absorber rods are used to control reactor power, and are driven by electric motors at the top of the reactor. When the reactor needs to be shut down (e.g., for fuelling), the control absorber rods are driven into the core, and the shut-off rods are left poised outside the core. Figure 5 shows the MAPLE reactor control room. Each MAPLE reactor is controlled by a programmable control system that includes control processors, input/output modules, communication components, a display system, printers, and a maintenance system. The Reactor Control Computer System (RCCS) senses the state of reactor systems by the signals it

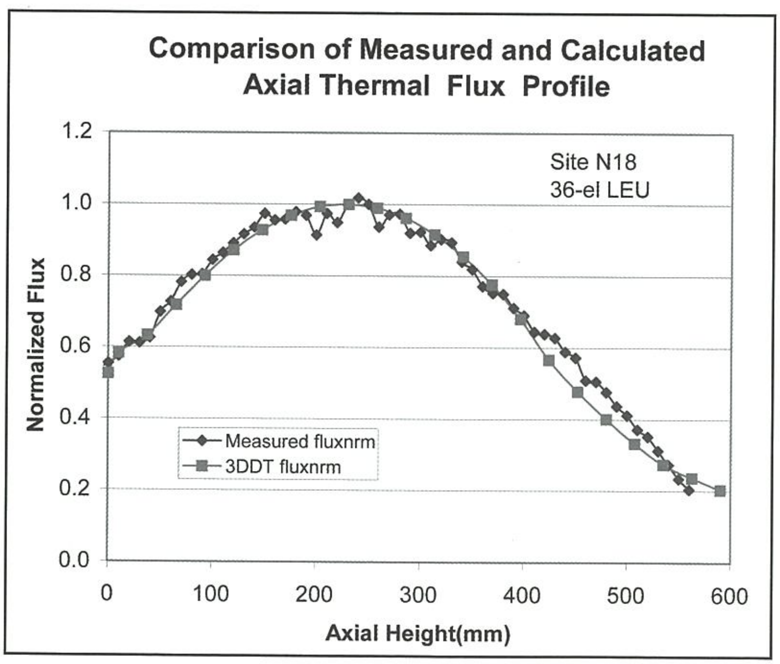

Fig. 4c) Normalized axial thermal neutron flux distribution at 36-element fuel site

receives from field instruments. The RCCS achieves control by manipulating elements of the control system such as the position of control absorber rods, opening of valves, etc. The RCCS performs the following main functions:

- power regulation,
- process control,
- system monitoring and alarming, and
- historical data storage.

The power regulation function controls the reactor power level by adjusting the vertical position of the control absorber rods.

The process control function is achieved by turning pumps on and off, adjusting throttling valves, and opening and closing isolation valves for the primary cooling system, reflector cooling system and process water system.

System monitoring consists of data collection from field instruments and from within the control algorithms. This data is available for display to the operator at the control console. Abnormal conditions initiate alarms and may also initiate the automatic shutdown of the reactor.

Selected data is recorded and stored by the display system. The data is available for display at the control console or may be exported for off-line analysis and/or permanent archiving.

4. Conversion to LEU

Studies have been underway since 1999 to assess the feasibility of converting isotope production in these facilities from a high to low-enriched uranium target to address USA nuclear non-proliferation initiatives.

In concert with the global trend to utilize LEU in research reactors, MDS Nordion has launched a three phase *LEU Target Development and Conversion Program* for the MAPLE facilities. The three phases are:

- Initial feasibility study;
- Conversion Development Program; and
- Conversion Implementation Program.

Phase 1, the Initial Feasibility Study, completed by AECL in May 2000, identified the technical issues to convert the MAPLE reactor targets from HEU to LEU for large-scale commercial production. This phase indicated that the main challenge to conversion comes from producing five times more uranium waste with LEU than HEU.

The second phase of the *LEU Target Development and Conversion Program* was developed with extensive consultation and involvement of experts knowledgeable in target development, process system design, enriched uranium conversion chemistry and commercial scale reactor operations and molybdenum production.

MDS Nordion is currently engaged with AECL, Argonne National Laboratory (ANL), and the Société

Figure 5: MAPLE Control Room

Générale pour les techniques Nouvelles (SGN) in a development program to assess options to manage the additional waste from medical isotope production using LEU. The Phase 2 Conversion Development Program will be completed in 2003, and will be followed by an assessment of the economic impact of converting the facilities to medical isotope production with LEU.

5. Conclusion

The MAPLE facilities are specifically designed for one purpose: the reliable, commercial production of medical isotopes. MAPLE 1 and 2 are the only privately owned reactors in the world that are designed exclusively to produce medical isotopes.

The combined strengths of MDS Nordion and AECL will capitalize on their extensive infrastructure, expertise and experience for the reliable, continuous production and supply of medical isotopes. The operation of the MAPLE facilities will be managed within an overarching culture of safety, superior performance, and a commitment to excellence.

AECL and the CNSC are engaged in a regulatory process that will ensure safety of design, an effective quality management program, reliability of operations, and protection of the environment. In fact, these will be the hallmarks of success for the project and its ongoing operations. Our strict adherence to such principles will enable Canada to remain as a premier supplier of medical isotopes to the international health care community.

Timely completion of the MAPLE project will ensure a secure, safe and reliable supply of medical isotopes, which is a priority for the global nuclear medicine community and for the patients who benefit from this technology. With the MAPLE facilities, Canada will continue to be the front-runner in medical isotope supply for many years to come.

Sustaining the Future: The Role of Nuclear Power in Meeting Future World Energy Needs

by Romney B. Duffey[1] and Yuliang Sun[2]

***Ed. Note:** The following paper was presented at the PBNC 2002 conference in Shenzhen, China, October 2002.*

Abstract

A description is given of recently informed analyses showing the potential that nuclear power has in meeting global energy demands. For both the electricity and transportation sectors, we can quantify the beneficial effects on the environment, and we show how nuclear power deserves credit for its role in assisting future world energy, environmental and economic sustainability.

The continuing expansion of the world's and Asia's energy needs, coupled with the need to reduce greenhouse gas (GHG) and other emissions, will require new approaches for large scale energy production and use. This is particularly important for China and Asia with respect to meeting both the energy demand and sustainability challenges. We show and explore the role of nuclear power for large-scale energy applications, including electricity production and hydrogen for transportation. Advanced nuclear technologies, such as those like CANDU's next generation ACR, can meet future global energy market needs, avoid emissions, and mitigate the potential for global climate change.

We use the latest IPCC Scenarios out to the year 2100 as a base case, but correct them to examine the sensitivity to large scale nuclear and hydrogen fuel penetration. We show a significant impact of nuclear energy on energy market penetration, and in reducing GHGs and other emissions in the coming century, particularly in the industrial developing world and in Asia. This is achieved without needing emissions credits, as are used or needed as economic support for other sources, or for subsidies via emissions trading schemes.

Nuclear power offers the relatively emissions-free means, both to provide electricity for traditional applications and, by electrolytic production of hydrogen, to extend its use deep into the transportation sector. For the published IPCC Marker Scenarios for Asia we show the reduction in GHG emissions when electrolysis using electricity from nuclear power assists the introduction of hydrogen as a fuel. Thus, nuclear energy assists in providing both environmentally and socially sustainable global economic and energy growth.

I. Introduction: The Nuclear Innovation Option

There is increasing awareness of the positive effect of electricity produced from nuclear power in reducing the increasing amounts of global Greenhouse Gases (GHGs) is at least a factor in the nuclear industry's perception of a coming revival in nuclear deployment. Several developed countries have already acknowledged that meeting their Kyoto Protocol objectives will not be possible without the incorporation of nuclear energy. Many countries that are now using nuclear energy have plans for increased use of nuclear in generating electricity in the next ten years.

While there is certainly scope for energy conservation in the developed world, the current low per-capita energy consumption in the developing world creates almost irresistible pressure toward a rise in global energy consumption. Energy and especially electricity consumption rise by factors of three to seven in all of the Intergovernmental Panel on Climate Change's (IPCC's)[1] scenarios for the 21st century. So abating GHG emissions is dependent on switching to fuels with intrinsically low CO2 emissions.

Innovations now underway in nuclear engineering and technology hold great promise and proven potential to significantly reduce GHG emissions that contribute to climate change. Our analysis shows that a technology-based Nuclear Innovation Option can mitigate or even reverse climate change by:

a) Adopting and building new and competitive zero-GHG emitting next generation Advanced CANDU Reactor (ACR)[3] plants as an alternative to fossil fuels.
b) Transitioning to the early use of hydrogen in transportation, with hydrogen produced from non-carbon sources using ACRs, at a rate and price consistent with new technology.

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c) Utilizing nuclear energy to unlock cogeneration energy production, without causing any increased production emissions.

The Nuclear Innovation Option can therefore contribute significantly to the world meeting its international commitments, provides an Option path forward that avoids any restraints on energy use or trade, and uses the latest nuclear technology. For both China and Canada, this is an important consideration to enable future sustainable economic growth.

2. Nuclear, Wind and Hydro have Near Zero Emissions

For each kilowatt of installed nuclear power, there can be "avoided emissions" of approximately 400 to 700 grams of CO2/kW*h*.

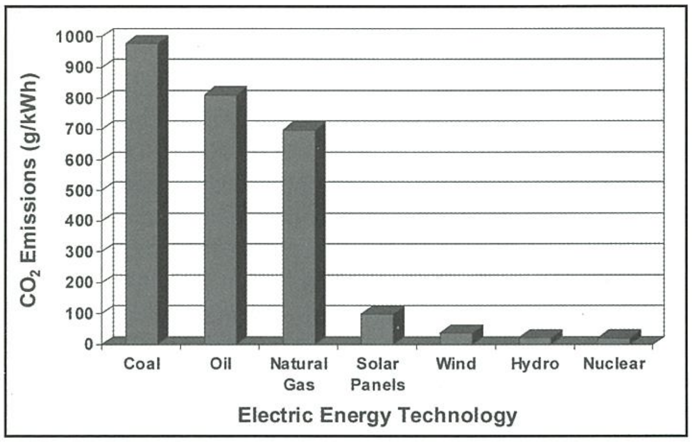

Figure 1: Relative carbon emissions from power sources (Sources: IAEA, GaBE Project, Hydro Quebec and NRCan)

The source of this data is the International Atomic Energy Agency (IAEA); the numbers are consistent with the European Union's "GaBE Project" results, with Hydro Quebec estimates, and with other independent studies in France and elsewhere.

Figure 1 shows the total life-cycle CO2 emissions to the atmosphere for different electricity generating sources. This includes the entire fuel cycle (including mining), plant construction, the plant operating life, and decommissioning and – at least for nuclear energy – waste disposal, so there is a full accounting and no emission amounts are hidden or allocated elsewhere.

The numbers correspond to avoiding about 5 million tonnes of CO2 per year (Mt/y) for a typical 600 MW(e) nuclear plant vs. a coal-fired plant, or 2-3 million tonnes per year vs. a modern combined-cycle gas turbine. Similarly, very large relative reductions also occur for other emissions, such as sulphur dioxide and nitrous oxides.

Now and in the future, China and Asia will have great challenges and pressure in the areas of both environmental protection (nationally) and GHG emissions reduction (internationally), particularly given the large use of coal-fired generation.

3. The Source of the Emissions

Emissions come from all sectors but the largest contributors are from transportation and electricity generation.

Figure 2 shows "equivalent" Carbon emissions in millions of tonnes into the atmosphere from the transportation sectors of the North American, European and Asian economies. These numbers are from Department of Energy's (DOE's) [2]

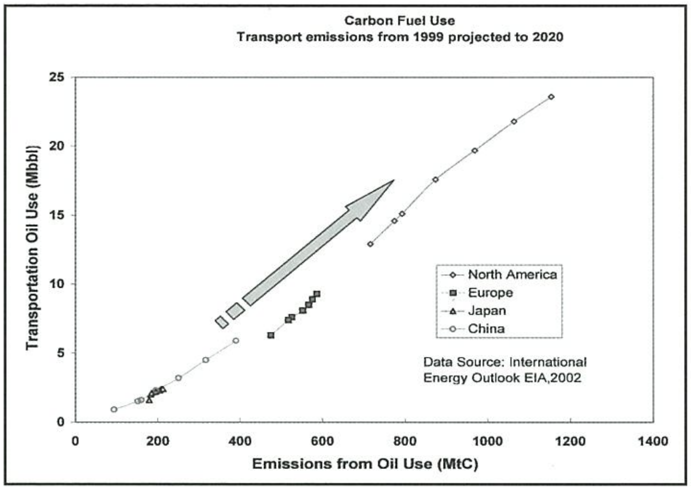

Figure 2: Emissions from oil use in transportation (Source: US Energy Information Agency, 2002) with the arrow showing the vector of the increases with time from 1999 to 2020

latest estimates and projections, spanning from the present out to 2020 assuming a modest rate of economic growth.

Note particularly that the transportation sector is the largest contributor and its contribution is expected to grow. It is also an important contributor to environmental pollution in the cities in China. As oil use rises, so exactly do the carbon emissions. Asia and others are also inexorably tracking the US and Europe into greater dependence on an imported energy (oil and gas based) economy. What this means is that we must examine both the power generating and the transportation sectors for the maximum contribution from innovation to both reduce emissions and dependence on imported oil.

4. Timeframes and Strategies: Beyond Kyoto

The Kyoto Accord contains measures that can cause implementation to have the potential for noticeable economic pain. But behind the detail of Kyoto lies international recognition

3 CANDU is a registered trademark of AECL and Advanced CANDU Reactor and ACR are trademarks of AECL

that the Earth's biosphere may lack the capacity to accept GHG emissions at current and projected levels without unacceptably dire consequences for the planet's climate. This recognition is implicit in international acceptance of the Kyoto Accord and worldwide it is sure that reductions greater than "5% below 1990 levels" will be needed. Indeed, the implication of the IPCC work is that cuts far beyond 50% are likely going to be required globally before 2050, and such measures are already being debated in Europe.

We suggest that such a longer-term, and far more demanding, requirement must remain prominent in plans to address the Kyoto targets. Very few of the possible solutions presently envisaged using conventional fuels are capable of causing even a 50% reduction in emissions.

Now this should not preclude pathways where small, short-term changes can be made at low cost (e.g., more efficient vehicles using conventional fuels). But we would suggest that the longer-term requirement ought to weigh heavily against some of the more disruptive responses. For example, any approach requiring substantial new infrastructure for an alternative fuel should be rejected unless it has the ultimate capability of delivering GHG cuts well in excess of 50%.

It is also important to note that ways of meeting the energy demand challenges are somewhat constrained by different national situations, with varying relative contributions of carbon energy sources.

5. Reduction of Emissions: Impact of Nuclear Innovations for Power Generation

Without the operating and refurbished nuclear plants, the world cannot meet any emissions reduction target by 2010 or beyond.

A large fraction (~7%) of the world's electricity now comes from nuclear power. Globally, this use of nuclear avoids burning of significant amounts of carbon fuels. The "big picture" numbers in terms of global environmental benefits are that 17% of the world's electricity that comes from nuclear plants avoids emissions of 2 to 3 billion tonnes of CO_2 annually.

For Asia, it is anticipated that the use of nuclear energy will grow as energy demand and use grows.

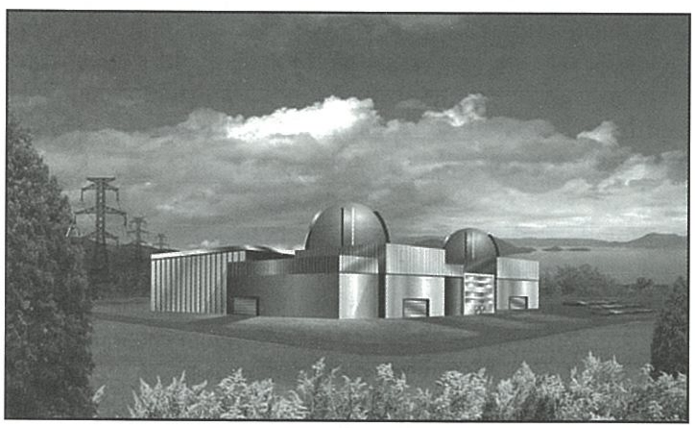

Figure 2: The New ACR-700 Concept (Source: AECL)

The nuclear innovation from Canada is the "next generation" of CANDU, which includes the new ACR series (Figure 3). The ACR is an evolutionary design that does not involve a leap in technology, and builds seamlessly on present experience. By optimizing the whole plant design, including an increase in efficiency of ~10%, and adopting a more compact layout, the capital target costs are significantly reduced (by over 40%) over current designs and competitors.

Competitive power markets demand a cost of ~$1000/kW installed. AECL is proceeding to design the low-cost ACR series for deployment in 2005 and beyond in Canada and large international (China, US, and UK) markets. The ACR is recognized as innovative by the International Generation IV Initiative, which include the U.S., Japan, France, U.K., Argentina and Korea. It scores highly against all the formal Evaluation Criteria used by the US DOE for assessing advanced concepts.

CANDU ACR can contribute significantly to future avoided emissions as well as to meeting the competitive power market, because the unit energy cost of the ACR is very competitive.

In much of Asia, natural gas is a low-cost competitor in the power market, but is sensitive to fuel price, whereas coal is the basic competition in China. Thus, nuclear should be in an advantageous position provided there is a competitive price. The need for energy security requires both options and a fuel mix that retains price stability.

Markets and investors require significant returns on investment also, and commercial funding of new plant construction is essential (with government guarantees only where necessary in the national interest). The competitive position for the ACR is retained for higher rates, and competes with gas and coal, thus giving it access to a large market "share". Thus, a large contribution from the ACR is expected in both the world and Asia's energy mix, with a potential to deploy the first units by 2009.

This low generating cost also makes electrolysis of water to produce hydrogen (perhaps during off-peak hours) economically attractive versus conventional methods.

6. New 21 st century Global Emissions Scenarios and Emerging Scientific Consensus on Climate Change

The threat from Climate Change is real, and the technical consensus is emerging.

Estimates of global future emissions for the 21 st century have been published by the United Nations IPCC. In its new report *(Figure 4)*, the IPCC predicts large increases in CO_2 and potentially adverse effects of Climate Change and potential global warming.

The "Emissions Scenarios" from the IPCC examine many alternate futures, including business-as-usual, and they allow for energy use growth consistent with the global economic and social growth patterns. Considerable energy use

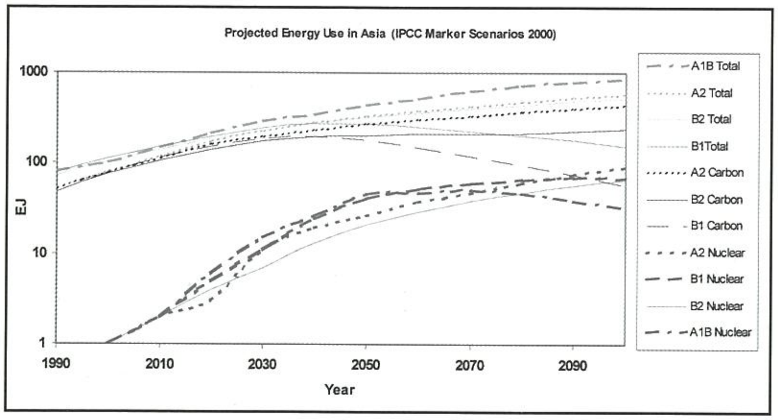

Figure 3: Recent scenarios for the 21st century predict significant effects, and new nuclear plants (Source: United Nations, 2000)

and economic growth occurs in developing nations. Four major scenarios (the "Marker Scenarios") cover most of the range of assumptions. All scenarios envisage increases in energy use, as well as in energy efficiency, renewable and nuclear energy use.

The IPCC's scenarios all include expanding nuclear deployment, in most scenarios growing by an order of magnitude by 2050 above the current level (see *Figure 3*). However, in its projections, the IPCC has assumed that nuclear will remain confined to supplying traditional electricity markets and modestly increasing the electricity shares. Consequently, and despite projecting substantial increases in energy supplies from other sustainable sources, none of the IPCC projections offer a solution to the build-up of GHGs in the atmosphere.

We contend that only a much greater reliance on nuclear power can stabilize GHG levels and halt the expected rise in global temperatures. And to realize the full potential of nuclear, its role will have to expand into energy sectors not traditionally supplied by electricity.

Applications of nuclear-produced steam can be added. However, the major opportunity is across the whole transportation sector through what has become known as the "hydrogen economy" with the hydrogen supplied by electrolysis of water using nuclear-generated electricity.

The innovative nuclear technologies on the near horizon (e.g., the CANDU ACR by 2005) and hydrogen-fuelled personal automobiles are both expected by 2005-2010, possibly preceded by heavier vehicles like city buses fuelled by hydrogen. For greatest effectiveness, transportation will likely convert hydrogen to electricity in fuel cells but hydrogen-fuelled internal-combustion engines are a possible bridging technology that at least one of the "Big Three" North American auto manufacturers is pursuing.

7. Innovation Option in Transportation Hydrogen Fuel

Much pressure and challenge can come from limited oil resources, as is the case in China. Hydrogen produced by electrolysis, using nuclear-generated electricity, offers a pathway with unparalleled potential for GHG reduction and sustainable development worldwide.

The source of hydrogen must be a non-carbon one. There are presently two economic and proven sources of hydrogen: natural gas reforming and electrolysis of water. However, using conventional natural gas reforming produces even more CO2, as energy is used to drive the primary endothermic reaction (39% more CO2 than simply burning the gas directly), whereas hydrogen from nuclear power does not produce GHG. Electrolysis is a standard process, and can use proven technology, easing up the natural gas demand.

In contrast, nuclear power is available virtually without limit and at low cost: the ACR series will produce electricity at a fully amortized cost of ~3 US¢/kW·h. Because nuclear power is not subject to the fluctuations of season or weather, this dependable electricity can be sold into the premium markets of peak demand, driving down the cost of electricity used to produce hydrogen during non-peak hours.

As an example, using the average yearly distance driven by North American vehicles (~20,000 km/y) and fuel cells at ~70% efficiency, a single ACR can supply enough energy to fully fuel ~600 to 650 thousand fuel cell vehicles each day. The avoided CO2 is roughly 5t/vehicle for each year (based on 20,000 km/y travel and current technology). Thus, one ACR avoids, using modern centralized or distributed home electrolysis cells at 70% efficiency for hydrogen production: 650,000 vehicles x 5t CO2 /vehicle ~3.25 Mt CO2/y.

Hydrogen-fuelled vehicles can be relatively easily added at a rate of 5% or perhaps more each year, corresponding to a conventional auto 20-year fleet turnover or life. This is compared to current transportation emissions, even excluding the emissions from production and distribution. Crucial to the introduction of hydrogen is that the electrolysis of water can be centralized or distributed, avoiding the issue

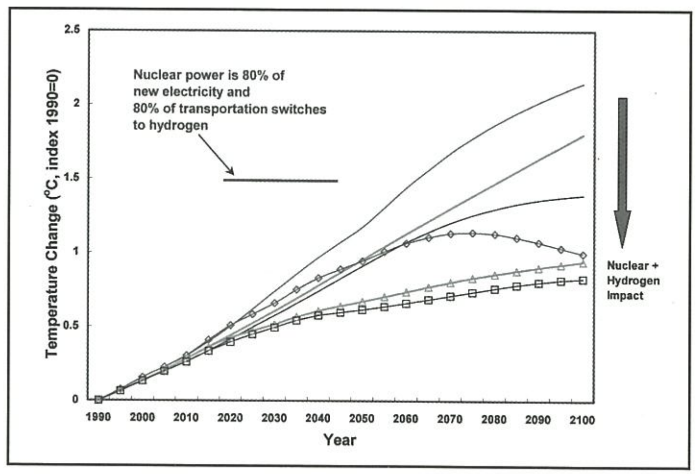

Figure 5: The Option of Reduction and Management of Climate Change (Source: AECL Results using MAGICC SCENGEN)

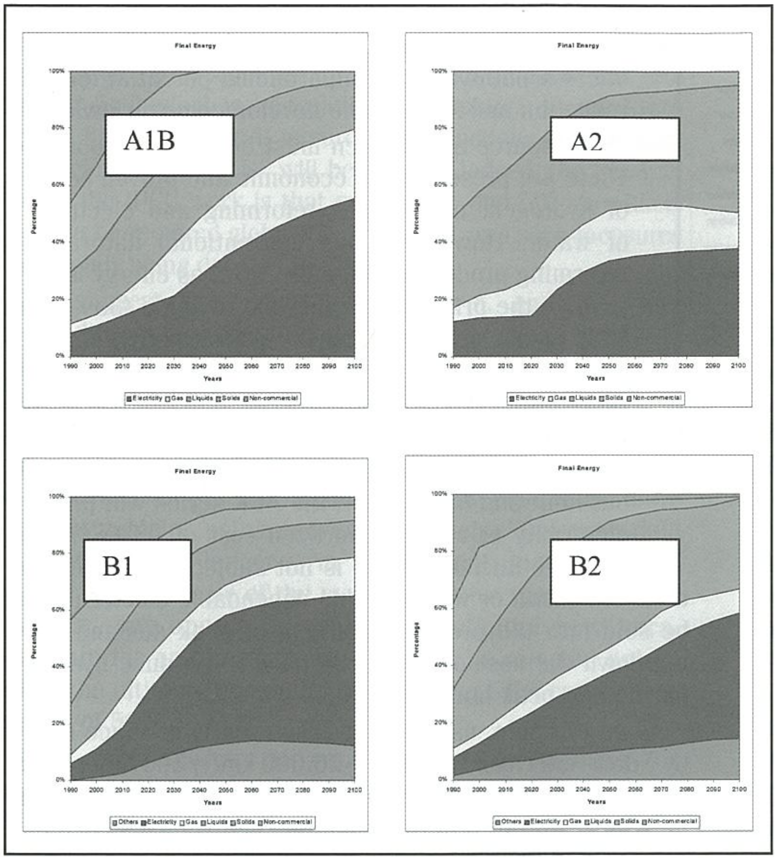

Figure 4: Final Energy Mix in Asia for Nuclear plus Hydrogen Fuel

of infrastructure for a new fuel. To the vehicle owner, the cost of fuel (hydrogen) is competitive even if off-peak electricity costs are as high as ~4 ¢/kW · h [3].

All the technology and innovation is already available, from a combination of ACR (AECL) and other fuel cell and electrolysis companies. In a typical transport sector, light road vehicles comprise about 50% of total energy use. Converting other forms of transportation to nuclear-electric hydrogen is likely to be even easier and the benefits would be no CO2 emissions from 80% or more of transportation, without the need to restrict most other carbon fuel use (e.g., in the industrial sector).

We have analyzed and quantified the impacts and benefits of these innovation Options.

8. Innovation Option: Reducing Power and Transportation Sector Emissions is Key to a Sustainable Future

The maximum impact on the 21 st century of new nuclear technology and innovation has been examined, and it is profound.

The IPCC scenarios were examined using a global energy use model (MAGICC) coupled with a model for climate change (SCENGEN)[4], which is a scoping tool for dynamic global analysis of GHG emissions from different energy sources. The outputs enable *relative* estimates of potential changes to the climate from GHG emissions. While not itself a model of the atmosphere, MAGICC SCENGEN was created to follow the effects predicted by the global atmospheric models and to allow exploration of climate change assumptions and their impact on global temperature and sea level as a function of the concentrations of carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O).

The IPCC Marker Scenarios themselves incorporate an expected span of different assumptions including population, land use, economic growth and the energy mixture. In the IPCC Marker Scenarios by 2100 nuclear energy is projected to contribute from between 3 and 30% of the global total. Nuclear energy is assumed to contribute even less than renewables in three of the four scenarios because its use is restricted to the scenario's electricity generating sector, and hence is not assumed to be deployed in transportation. In addition, the IPCC assume a generating cost of 9 ¢/kW · h for new NPPs, whereas "Generation IV" designs are actually targeted at less than 3 ¢/kW · h. These major differences in assumptions alone can markedly shift the results and mixes that are defined above.

Using the IPCC Marker Scenarios as a baseline, the overall timeline was designed to determine the maximum extent of the nuclear contribution:

1) 5% of transportation energy using hydrogen fuel is introduced by 2020, such that
2) 80% of transportation energy using hydrogen fuel is introduced by 2040, so
3) 20% of the carbon energy used for transportation worldwide is displaced, and
4) 80% of new electricity will be produced by either nuclear or renewable energy sources by 2020 and beyond.

In contrast to the IPCC's original scenarios, the case results shown indicate that Climate

Change is mitigated and even reversed by using today's technology in the 21 st century (see *Figure 5*).

We can show the detailed potential impact for Asia, by taking the Regional estimates from the Marker Scenarios. Example results for the final energy mixes for the IPCC Marker Scenarios are shown in Figure 6. We can see that electricity could become ~50% of the final energy use mix in Asia, thus making the Region highly independent in energy supply by using and adopting new technology. *This is a radical and extremely different vision for the future energy supply than exists today, and is consistent with moving towards a sustainable energy and economic future.*

9. The Estimated "Value" and Cost of Avoided Emissions

To estimate the cost of CO2 reduction, we have used an economic analysis to estimate the effective capital net present cost of different options, and takes no credit for any revenue generation or other benefits.

On the basis of the analysis, the cost of deploying ACRs to generate electricity needs no further justification from the viewpoint of reduced emissions. CO2-reduction through the nuclear option has negative costs (or a positive benefit) against coal and against CCGT fuelled by natural gas (even at the fairly moderate natural gas price of 2.7 $/GJ used for this study). No "carbon" trading credits has been assumed, but could be valuable in offsets from 2010.

10. Conclusions

In all four variations of the IPCC Marker Scenarios, the introduction of nuclear energy and hydrogen fuel from non-GHG emitting sources can have a profound effect on the reduction of global and national GHG emissions, and, subsequently, on GHG atmospheric concentrations and global temperature rise. This is particularly important for Asia and China in meeting future energy demand and sustainability requirements. Also, the variations analysed confirm that the world will need to make a significant shift away from GHG-emitting fuels just to stabilize the impact of GHG emissions within the next 100 years.

In all scenarios, the postulated increases in the role of nuclear and other non-CO2 emitting energy sources produce reductions in the estimated temperature increases that are at least as large as the observed temperature rise in the 20 th century attributed to GHG emissions.

This analysis shows that:

1. Innovative CANDU nuclear power will have a large impact on the reduction of GHGs and other airborne pollutants, and this is a very advantageous position for nuclear competing versus coal.
2. Economic benefits would be very high, including reduced energy import requirements,and reduced emissions for the power generation and transportation sectors, also relieving dependence on imported oil.
3. Globally the use of hydrogen and nuclear can stabilize and even reduce potential Climate Change for all the reasonable growth scenarios studied.
4. Innovative nuclear (plus hydrogen technologies) should be part of the global proposals for reducing GHG emissions.
5. The innovative (ACR) nuclear route is actually cheaper at a lifetime 10%/a NPV basis than coal- or natural gas-fuelled alternatives.

11. References

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Thirty years of Reactor Physics at Pickering

by M.K. O'Neill[1]

Ed. Note: *The following paper was presented in the opening plenary session of the 22nd Nuclear Simulation Symposium held in Ottawa, November 2002.*

1 Introduction

The central problem in reactor physics is the determination of the neutron flux. The purpose of this paper is to summarize the experimental basis of reactor physics at Pickering. We will review experimental data obtained over 30 years of operation and examine the extent to which such data and reactor testing can be used to confirm the adequacy of our theoretical understanding of Reactor Physics.

1.1 Importance and Limitations of Experiments

Karl Popper (and others) have argued that scientific theories are those which can be shown to be incorrect by experiment or observation 1 . The corollary of this assertion is that accuracy of a theory is directly tied to the accuracy of the measurements and *that the accuracy of a theory can never exceed that of the experimental basis*. A familiar example is that of the electron neutrino:

The standard theory holds that the neutrino has a rest mass of zero, whereas the experimental results can only confirm that the rest mass is less than 3 eV 2. Similarly, experimental evidence can only state that the photon rest mass is less than 2x10 -16 eV.

It should be noted that this view enhances (rather than diminishes) the power of the scientific method, in that it permits the development of theories which predict new phenomena, while maintaining consistency with both the existing experimental basis and the theoretical underpinnings. In the examples above, novel theories involving massive photons and neutrinos already exist. Furthermore, when a theory is shown to be at odds with experiment, we are forced to develop a new theory (e.g. the discovery of magnetic monopoles would certainly require a modification to electromagnetic theory).

2 Background

2.1 Station Description

Pickering Nuclear is an 8 unit station located east of Toronto on Lake Ontario.

The first four units (Pickering NGS A) were placed in service over the period of 1971-1973, and were retubed over the period of 1985-1990. These units were shutdown and placed in a "laid-up" condition in 1996. They are currently being returned to service. The second four units (Pickering B) were commissioned and placed in service over 1983-85 and have been in-service since that time.

Table 1 lists the In-service dates for each unit. **Table 2** lists key reactor unit information. For comparison purposes data pertaining to Darlington are included..

3 Methodology and Technical Issues

3.1 Reactor Physics and Measurements

In general, Reactor Physics measurements have been conducted to confirm design functionality or operational capability during commissioning and related testing. The types of Reactor Physics measurements fall into the following categories:

- Criticality measurements
- Reactivity device worth measurements
- Reactivity coefficient measurements
- SDS Rundown tests
- Flux mapping measurements
- Neutron flux detector response measurements
- Channel power measurements

3.2 Simulation and Theoretical Tools

With the exception of the initial commissioning for Pickering A units (1972-73), the reactor physics measurements at Pickering have been verified and/or

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compared against predictions from the historical toolset (PPV/MULTICELL/OHRFSP/SMOKIN). These predictions and simulations form the design basis for the Pickering reactors.

For the most part, comparisons of the Pickering B experimental data against predications by the Industry Standard Toolset (IST) have not been conducted. These will be performed as part of the IST program in the coming years.

3.3 Measurement Techniques and Limitations

Measurements of reactivity involve either laboratory analysis of moderator poison samples, or changes in LZCS, both with inherent uncertainties and limitations. In the case of the former, lab analysis uncertainty is at least 5%. Furthermore, "burnout" (isotopic depletion) will systematically affect the results of chemical analysis, making this technique of limited use under high power conditions. In the case of the latter, indicated zone level is strongly influenced by the LZCS compressor cycle and can vary by as much as 5%. While various techniques can be used to minimize the impact of process uncertainties, the level of "irresolvable measurement error" is in the order of 5% for a given measurement.

3.4 Acceptance criteria

The acceptance criteria in place at Pickering for reactor physics Testing and Commissioning 3 has been developed based on practical experience which reflects instrumentation capability and other operational uncertainty. **Table 3** summarizes the criteria.

4 Overview of Reactor Physics Measurement and Testing

Tables 4a and 4b present the major testing programs which have been conducted at Pickering over the past thirty years and the results are presented in the sections which follow.

4.1 Pickering A

Table 5 presents selected commissioning results following Retube/Rehab. The data presented is typical and it can be seen that there is good agreement between the predicted results and the measurements.

4.2 Pickering B

Table 6(a) presents the summary of results from the commissioning tests for Units 5,6,7,8. The data presented is typical and it can be seen that there is good agreement between the predicted results and the measurements.

Table 6(b) presents FDRP results. As can be seen, the measurements of detector response to various reactivity device movements is in excellent agreement with predictions.

Table 6(c) presents the summary of results from adjuster rod changes that have been performed in support of the cobalt program over the years. The data presented is typical and it can be seen that there is good agreement between the predicted results and the measurements.

4.3 Other Reactor Physics Measurements

Accurate estimates of neutron source strength are essential to safe and efficient unit start-ups after outages. **Figures 1(a) and 1(b)** present ATC results over the past 6 years. The trends lines shown, which were derived from the historical data, are now used to predict unit condition at criticality. Excellent agreement exists, as is demonstrated by recent ATC events.

Rundown tests are performed per the commissioning specifications. Typical results are shown in **Figures 2(a) and 2(b)** from the Unit 8 commissioning reports.

Flux scans using both activation and fission chamber techniques have been employed at Pickering over the years. **Figure** 3 presents typical results from Unit 8 using a manually operated fission chamber system.

5 Discussion and Conclusions

As noted in the introduction, experimental results are the only means by which the accuracy of theoretical models can be calculated. This paper has reviewed the measurement and test data related to reactor physics accumulated over 30 years of operation at Pickering. We can draw the following conclusions:

- In general, the measurements are in good agreement with prediction, and accuracies of ~10% can be supported.
- Systematic errors in adjuster rod worths have been observed in a variety of AA rod designs (both cobalt and stainless steel). These errors have been attributed to (in part) inherent weaknesses in the use of MULTICELL to generate incremental cross-sections.
- The verification of small reactivity changes (such as those associated with reactivity coefficients) is difficult given the uncertainties associated with LZCS measurements.
- Rundown tests have demonstrated that the Shutdown Systems meet the Safety Report assumptions regarding reactivity insertion rate and effectiveness.
- Flux detector response tests demonstrate excellent agreement with prediction. This is an interesting result, in view of the aforementioned issues with moveable devices.
- Flux mapping measurements are consistent with general predictions regarding flux profiles in the reactor core.
- A reliable model of shutdown source term has been

developed which facilitates accurate predictions for ATC evaluation.

The results also establish that the historical toolset (OHRFSP/PPV/MULTICELL/SMOKIN) is capable of modeling reactor physics with accuracies approaching the limits of normal reactor instrumentation. Having said that, it is hoped that the IST will address some known deficiencies, particularly those around the calculation of incremental cross-sections for moveable devices.

The author gratefully acknowledges the contributions of M. Dobrean, R. Hilliard, and E. Sorin to this report..

Table 1 Unit In-Service Dates

UNIT	MCR	MCR	First	FIRST	IN-SERVICE
	Gross	Net	Critical	ELECTRIC	DATE
P1	542	515	Feb 25/71	Apr 4/71	Jul 29/71
P2	542	515	Sep 15/71	Oct 6/71	Dec 30/71
P3	542	515	Apr 24/72	May 3/72	Jun 1/72
P4	542	515	May 16/73	May 21/73	Jun 17/73
P5	540	516	Oct 23/82	Dec 19/82	May 10/83
P6	540	516	Oct 15/83	Nov 8/83	Feb 1/84
P7	540	516	Oct 22/84	Nov 17/84	Jan 1/85
P8	540	516	Dec 17/85	Jan 21/86	Feb 28/86

Table 3 Acceptance Criteria

Measurement Category	Criteria
Liquid Zone Control System Reactivity Worth (mk)	+/- 15%
Adjuster Rod Reactivity Worth (mk)	+/- 15%
Control Absorber Reactivity Worth (mk)	+/- 15%
SOR Reactivity Worth (mk)	+/- 10%
SDS Rundown	Meet Safety Report assumptions

Table 4(a) Summary of Major Reactor Physics M&T Programs: Pickering A

Program Description	Time Period	Summary of Testing
RP testing per original commissioning specifications	Sept 1971 to Sept 1973	Criticality measurements Reactivity device worths Reactivity coefficients SDS Rundown tests Flux mapping
RP testing per post retube commissioning specifications	Sept 1987 to Sept 1990	Criticality measurements Reactivity device worths Reactivity coefficients SDS Rundown tests Flux mapping
Cobalt Adjuster Rod changes	1987 to present	Adjuster rod worths
SDSE commissioning	Sept 1993 to Sept 1995	Fission chamber tests ICFD response testing
PARTS	Jan 2003 to Dec 2004	Criticality measurements SDS Rundown tests SDSE commissioning

Table 4(b) Summary of Major Reactor Physics M&T Programs: Pickering B

Program Description	Time Period	Summary of Testing
RP testing per original commissioning specifications	Sept 1971 to Sept 1973	Criticality measurements Reactivity device worths Reactivity coefficients SDS Rundown tests Flux mapping
RP testing for FDRP program retube commissioning specifications	Sept 1987 to Sept 1990	Neutron flux detector response Channel power measurements
Cobalt Adjuster Rod changes	1987 to present	Adjuster rod worths

Table 5 Selected Pickering "A" T&C Results

Post Retube/Rehab Commissioning (Unit 4)

Measurement	Predicted	Measured
Critical Poison Concentration (ppm B)	10.4	10.9
LZCS Worth (mk)	4.92	4.45
Adjuster Rod Worth - Total (mk)	9.5	9.9
Individual SOR worth (%)	-	Predicted value +15%

Table 6(a) Selected Pickering "B" T&C Results

Initial Commissioning (Unit 8)

Measurement	Predicted	Measured
Critical Poison Concentration (ppm Gd)	2.6	2.62
LZCS Worth (mk/%)	0.079	0.069
Adjuster Rod Worth - Total (mk)	17.5	17.6
Control Absorber – average (mk)	1.78	1.9
Individual SOR worth (%)	-	Predicted value +/- 3.9%

Table 6(b) Selected FDRP T&C Results

Predicted vs. Measured Detector Response to Device Movement (Unit 7)

Measurement	Mean	Std. Dev.
Adjuster Rod AA5	0.96	1.85
LZCS	0.61	0.71
Control Absorber CA1	-0.91	1.61
Shutoff Rod SA8	-0.80	1.24
Safety Report (NOP) assumptions	0.0	3.5

Table 6(c) Cobalt AA Rod Commissioning Results

Measurement	Predicted	Measured
Adjuster Rod Worth U6- Total (mk)	19.5	16.3
Adjuster Rod Worth U8- Total (mk)	19.5	16.6

Table 2: Comparison of Nuclear Generating Stations (from Pickering B Safety Report)

ITEM	PICKERING A	PICKERING B	DARLINGTON
Unit electrical output MV(e) (net)	515	516	881
Number of Units	4	4	4
Core and fuel data			
Maximum licence 100% reactor power MW(th)	1744	1744	2776
No. of channels	390	380	480
Maximum licenced 100% channel power MW(th)	6.1	6.1	7.2
No. of bundles/channels	12	12	13 (12 in core)
Maximum licenced bundle power kW(th)	750	750	1035
No. of elements/bundle	28	28	37
Average fuel element power kW(th) (based on licenced bundle power)	26.8	26.8	28.0
Direction of refuelling	With flow	With flow	Against flow
Minimum pressure tube wall thickness, mm	4.06	4.06	4.2
Reactivity Mechanisms in Service			
Adjuster rods (absorbers)	6 (SS)	21 (SS/Co) [a]	18 (SS)
Reactivity Control	LZCS, plus Moderator Level Control	LZCS, plus 4 Control Absorbers	LZCS, plus 4 Control Absorbers
Vertical flux detector assemblies	6	14 (Units 5,6,7) 20 (Unit 8)	23
Horizontal flux detector assemblies	-	7	14
Primary shutdown mechanism	23 shutoff rods augmented by moderator dump [b]	28 shutoff rods	32 shutoff rods
Secondary shutdown mechanism		6 Poison injection nozzles	8 Poison injection nozzles
Heat Transport System			
Reactor inlet header temperature °C	249	249	267
Reactor outlet header temperature °C	293	293	310
Quality in reactor outlet header at 100% FP	5°C subcooled	7°C subcooled	2.0 wt%
Reactor outlet header pressure MPa(a)	8.83	8.83	10.0
Main system volume, m^3	139	139	217
Heavy Water inventory at 38°C m^3/MW(e) [c]	0.317	0.317	0.25
No. of steam generators	12	12	4
No. of pumps	12 + 4 spare	12 + 4 spare	4
Pressure control	Feed and bleed	Feed and bleed	Pressurizer

NOTES

(a) Provision has been made to use Cobalt in Units 6, 7 and 8, Unit 5 retains SS AA rods.
(b) Since Pickering A has a moderator dump system, a spray cooling system is provided to cool the calandria tubes.
(c) Excluding requirements for pressurizer and auxiliary systems.

Figure 1(a): PB ATC Experience Reactor Power at Criticality and Number of Power Doubles at Rationality

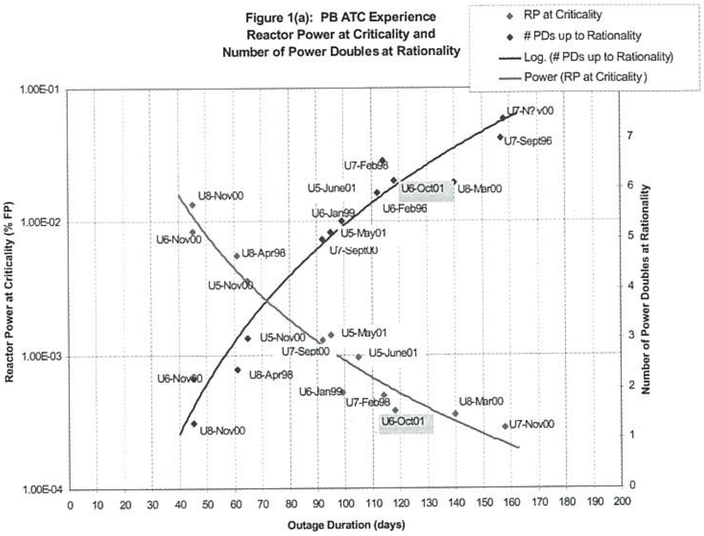


Figure 2(a): Typical SDS1 Rundown Data from Unit 8 Commissioning Report

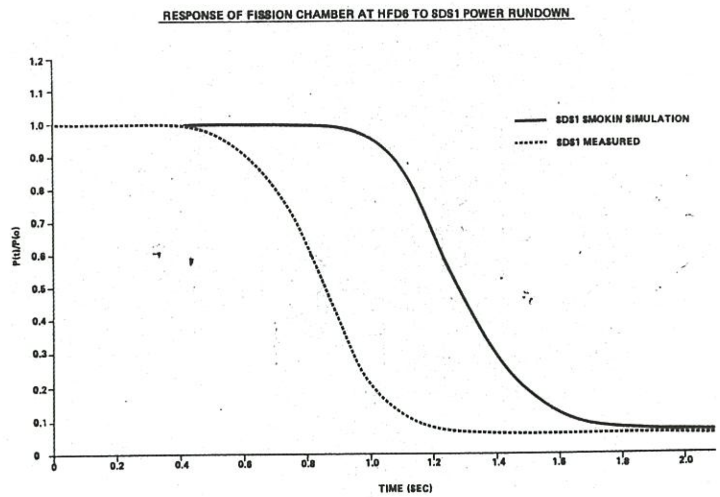


Figure 1(b):PNGS A & B: ATC Experience (Outages greater than 90 days)

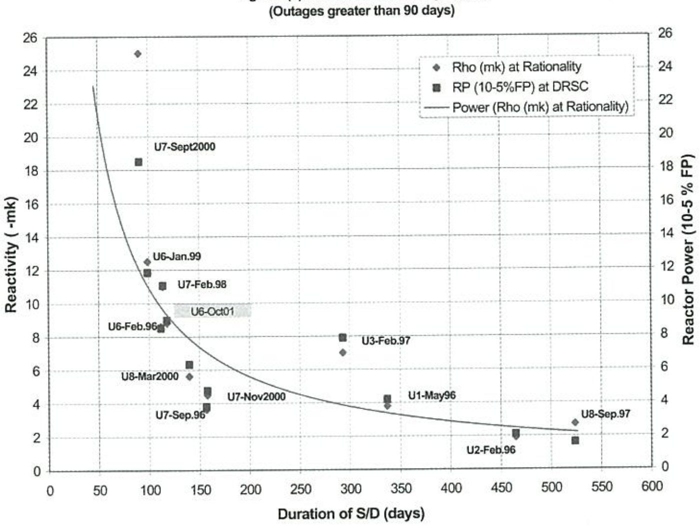


Figure 2(b): Typical SDS2 Rundown Data from Unit 8 Commissioning Report

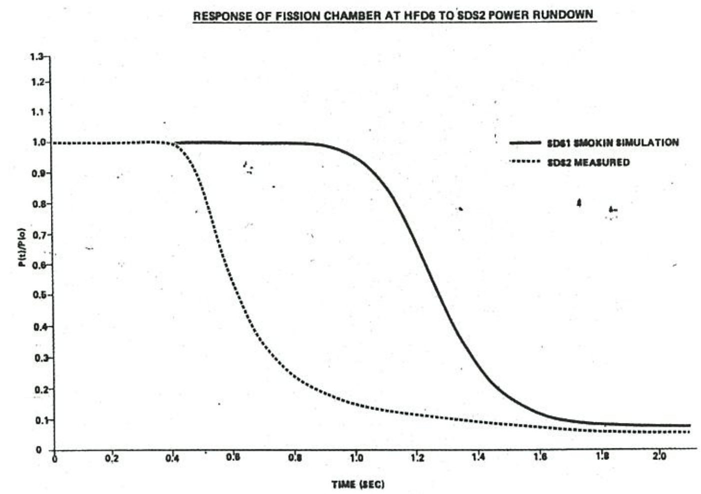
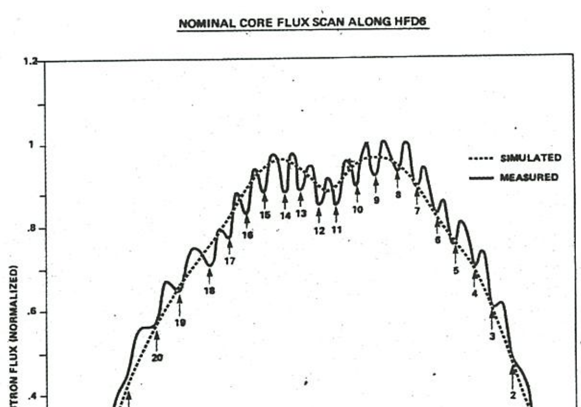


Figure 3: Typical Flux Scan Data from Unit 8 Commissioning Report



Learning the hard way

- An early accident at the NRX reactor led to improved design of subsequent reactors and the development of a distinct Canadian approach to reactor safety

by Fred Boyd

Accidents are never welcomed. Certainly the accident to the NRX reactor at the Chalk River Laboratories just over 50 years ago, in December 1952, was a shock to those involved and could have led to the demise of the fledgling Canadian nuclear program that had begun less than a decade earlier or of the company that had just been created to carry forth that program, Atomic Energy of Canada Limited.

However, everyone responded positively, from workers on the scene to management to the responsible minister, C. D. Howe. As soon as the reactor was restored to a safe condition plans were begun for its dismantling and reconstruction. Part of that story is in the companion article on the NRX accident.

Perhaps most significant in the long term, the accident prompted several people to study the whole question of reactor safety, from the objectives to their achievement. Some of the early thoughts were focussed on the control system, understandably since the accident resulted from a control failure. These bore fruit quickly in the design of the control system for the NRU reactor, then beginning construction, and the introduction of parallel channels which could be tested while the reactor was running.

Since power reactors were already being considered there were several suggestions about the objective. Some of these, notably by Ernie Siddall and George Laurence, looked at the general standard of safety of industry, especially of those activities that might be comparable to electrical generating plants. From observation of what was then accepted practice both Siddall and Laurence came up with a target of 10^{-2} deaths per year.

Then came the challenge of how to achieve this and, perhaps more importantly, how to demonstrate its achievement. Probabilistic analysis had not yet been developed and, in any event, as Laurence noted, good data on failure rates was inadequate or, for new designs, non-existent. The risk was from a "disastrous" release of fission products. Taking the pessimistic assumption that a "disastrous" release could lead to a 1,000 deaths Laurence suggested a target for such a release of less than 10^{-5} per year

Laurence then began proposing that a power reactor design could be considered in three parts - the normal operating or "process" systems; the protective devices; and a containment system. He initially proposed that significant failures in the process system could be as high as 1/10 per year. For the (standby) protective and containment functions he looked at their availability, i.e., their ability to respond as needed. With practical monitoring he proposed that these systems might be "unavailable" one day per year, giving a probability of them not functioning of about 10^{-2}. Provided the process, protective and containment were sufficiently independent the likelihood of a failure that would lead to a significant release of fission products would be $10^{-1} \times 10^{-2} \times 10^{-2} =$. 10^{-5} per year. (1)

Laurence had been appointed chairman of the Reactor Safety Advisory Committee (RSAC) by the Atomic Energy Control Board in 1956 and much of his thinking was done in the context of that committee. In 1964 the RSAC produced a "Reactor Siting and Design Guide" and sent it to the designers of the Pickering (A) generating station. That document continued the concept of the three divisions of the plant and set "reference dose limits" for a "single failure" of the process equipment and for a "dual failure" of a process failure combined with unavailability of the protective or containment systems. The assumed process failure rate was 1/3 per year and the required unavailability of the protective or containment systems was set at 10^{-3}.

Although a number of specific design requirements were included some were contested by the designers and not enforced.

By 1970 the concept had evolved to considering the various protective and containment systems as "special safety systems" and was set out in a paper initially issued by the AECB in 1972 (2).

The proposed design of the Bruce (A) plant with its much smaller containment precipitated a further development. The designers proposed a second "emergency" shutdown system because there was uncertainty that the containment could cope with a loss-of-control plus failure to shutdown (runaway accident). After considerable debate the RSAC ruled that the approach was acceptable if the second shutdown system were fully equivalent to the primary one. This was formalized in one of the AECB's first "regulatory documents"(3). Subsequently, in the early 1990s the AECB issued specific regulatory documents on the requirements for containment, shutdown and emergency cooling systems (4) (5) (6).

Although the development of probabilistic safety assessments has, to some degree, superseded some of these earlier approaches, the concept of separation of safety systems remains as a fundamental aspect of the Canadian reactor safety philosophy.

(1) G.C.Laurence — *Required Safety in Nuclear Reactors* — AECL 1923 — 1961

(2) D.G. Hurst, F.C. Boyd — *Reactor Safety and Licensing Requirements* — AECB 1045 — 1972

(3) .... — *Use of Two Shutdown systems in Reactors* — AECB R-10 — 1977

(4) .... — *Requirements for Containment Systems for CANDU Nuclear Power Plants* — AECB R-7 — 1991

(5) .... — *Requirements for Shutdown Systems for CANDU Nuclear Power Plants* — AECB R-8 — 1991

(6) .... — *Requirements for Emergency Core Cooling* Systems for CANDU Nuclear Power Plants — AECB R-9 — 1991

A historical note:

The NRX Accident

***Ed. Note:** The following article is reprinted, with very minor corrections, from one in Vol. 13, No. 4 issue of the CNS Bulletin, Winter 1992*

On a Friday December afternoon just over 50 years ago an event occurred which would have a significant effect on the Canadian nuclear program, especially on the development of reactor safety philosophy.

During preparation for reactivity measurements at low power, on **12 December 1952**, "a complex concurrence of mechanical defects ... and operating errors ... resulted [in] a power surge in the NRX reactor."

This major accident, the most serious in the history of the Canadian nuclear program, resulted in melting of some of the uranium metal fuel and the release of an estimated 10,000 curies (about 4×10^8 MBq) of fission products into about 1,000,000 gallons (over 4,000,000 litres) of (light) water which was contained in the basement of the NRX reactor building.

The following accounts (and the quote above) are taken from the official report on the accident by Dr. W.B. Lewis, issued in 1953, and a 1955 paper by G.W. Hatfield.

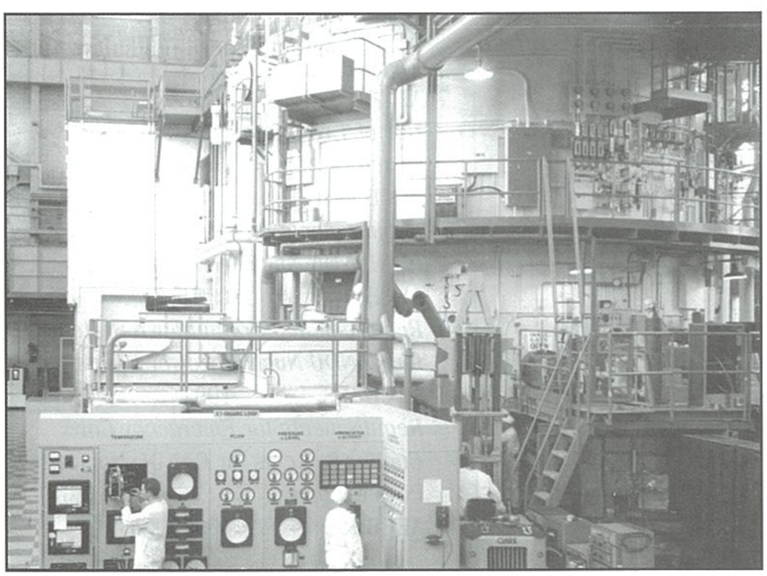
(from "The Accident to the NRX Reactor on December 12, 1952"by W.B. Lewis, AECL-232).

Overview

During preparation for reactivity measurements the reactor was unexpectedly found to be divergent, and at the same time there was some mechanical defect preventing shut-off rods from dropping in.

Even this would not have had serious results if a number of the uranium rods had not at the time a purposely reduced flow of cooling water. As the reactor was leveling off in power at about 17 megawatts, the cooling water of these rods boiled, thereby increasing the reactivity and the power. At the increased power, some of the aluminum sheathing the uranium melted. At least one rod blew itself apart, and molten uranium poured out from the core of the upper part. Some of the tubes retaining the heavy water ruptured. All the fluid systems of cooling water, air, heavy water, and helium were then in contact. The cooling water being under the highest pressure was forced in, displacing air and helium, and helped to bring the reactor below critical.

Meanwhile, however, the operators had been forced to their last resort; namely, to open valves which dumped the heavy water rapidly to storage tanks below. Within 60 sec the power was back to zero, but major problems of radioactive contamination had been set." [The shut-off rods were free falling, with air pressure used to provide an initial acceleration. They were raised by air pressure.]



A view of the NRX reactor taken in the 1960's.

Reactor Loading and Intended Operation

The experiment on hand was a series of measurements of the reactor reactivity at low power. The main object was to compare the reactivity of long-irradiated rods with that of fresh rods. To avoid complications from dimensional changes in the water-cooling channels, it was necessary to blow the water out of some rods and substitute air cooling. At the time of the incident only one rod was air-cooled and that was a fresh unirradiated rod. All enriched fuel rods, adjuster (cobalt load) rods, special assemblies, and isotope loads were out of the reactor except one thorium and uranium sample rod in an outer region.

A full complement of normal uranium rods was in position. Certain of these rods were to be moved between measurements and had only temporary cooling by means of hoses. Such cooling is adequate for low-power operations.

As the reactor had not been up to power for several days, transient poison had decayed, a necessary condition for the experiment.

Because of the experiments in hand, research physicists were present in the reactor control room, but the reactor was operated by the reactors branch personnel who alone have authority for this. The reactor loading to be used was recommended by the physicists and approved in writing by the reactors branch superintendent."

Description of the Incident

The immediate chain of events which led to the accident began with an error by an operator in the basement who opened by mistake three or four bypass valves on the shut-off-rod air system, thereby causing three or more shut-off rods to rise when the reactor was shutdown. The supervisor at the control desk noticed this because the red lights came on. He phoned to the operator in the basement to stop and went down himself to investigate and rectify the situation, leaving his assistant at the control desk.

He recognized the operator's mistake and was horrified at the possible consequences if the operator had continued to open these wrong valves (actually he could not have opened all valves since some handles had been removed for safety). The supervisor rectified all valves and checked air pressures. He assumed that all shut-off rods would drop back into position, but, on account of unexplained mechanical defects, it is apparent from subsequent events and inspection that two or three did not drop back, although they slipped down sufficiently to clear all the red lights on the control desk.

The supervisor then phoned his assistant to press buttons 4 and 1. He had intended to say 4 and 3, but under normal circumstances 4 and 1 should have been safe (all the shut-off-rod red lights were out). His assistant therefore did so. Having to leave the phone to reach simultaneously with two hands the two buttons, he could not be recalled to correct the mistake. Button 3 having been pressed, the air pressure brought up by button 4 leaked away." [Button 4 charged air to the heads of the shut-off rod assemblies to provide the initial acceleration. Button 1 raised bank #1 of the shut-off rods. Button 2 raised the remainder of the shut-off rods. Button 3 increased temporarily the current in the solenoid magnets used to hold the shut-off rods in the up position.]

Up in the control room it was soon evident when the first bank of shut-off rods was raised by button 1 that the reactor was above critical, which was of course a complete surprise. It takes a few seconds for this to be apparent. There was surprise but no alarm, for the next step would be to trip the reactor and thus drop back the shut-off rods. This the assistant did about 20 sec after pushing button 1. But two of the red lights stayed on, and in fact only one of the four rods of the first bank dropped back into the reactor and that over a period of about 1 1/2 min. Even though, as it appeared, the air pressure had leaked from the header, all shut-off rods should have nevertheless dropped back under gravity.

The galvanometer spot indicated that the power level was still climbing up. The assistant telephoned the supervisor in the basement urging him to do something to the air pressure to get the rods down.

Others in the control room were worried: the physicists, the assistant superintendent of the reactors branch, and a junior supervisor. At least two thought of the last resort: namely, to 'dump the polymer.' All were familiar with the process as it had been done the previous day for experimental purposes. The assistant superintendent gave the word; one of the physicists was already reaching for the dump switch and beat the others to it.

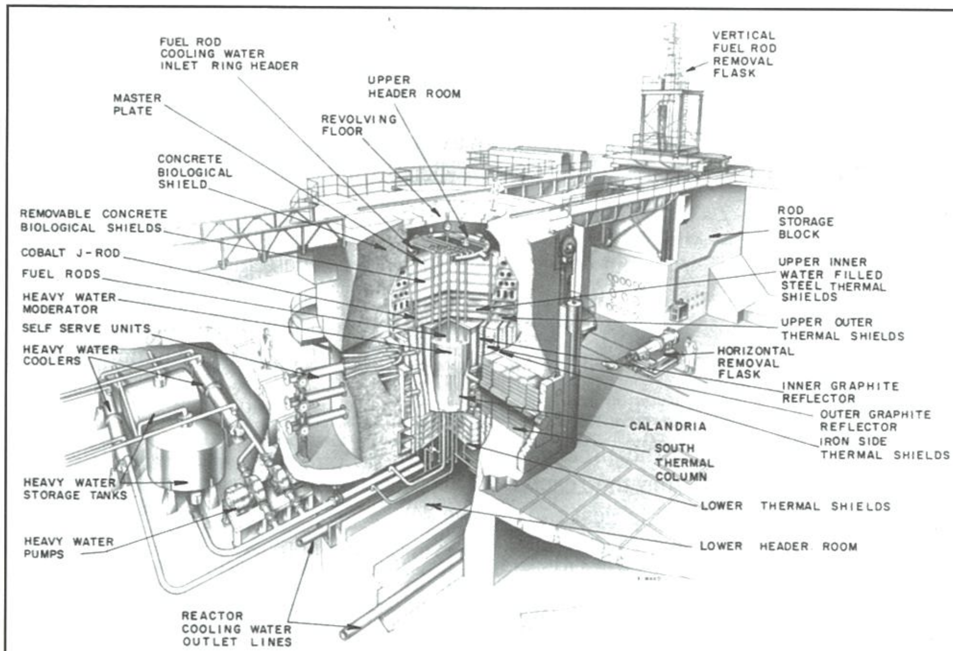
However by this time the reactor power was up in the tens of megawatts, and the dumping took a few seconds to become effective. Then a fear arose that they might be dumping too fast as the helium pressure had dropped back sharply, and they envisaged danger of collapsing the calandria by vacuum. The assistant superintendent halted the dumping after about 1 min but after a little thought resumed it. However, in 10 to 30 sec after starting to dump, the instruments were back on scale, and the power rapidly dropped to zero. The assistant superintendent went to report to the superintendent, but the consequences were only beginning.

In the basement the door into the chamber under the reactor (the lower header room) was open. Through this an operator saw water gushing down, and immediately he called the supervisor. Their instant reaction was to suspect any water as being heavy water; therefore the supervisor and operator rushed in with a bucket and collected a sample, which was soon found to be light water but radioactive.

The assistant superintendent, returning to the control room, was met by an operator who reported a rumble and a spurt of water up through the top of the reactor.

Then the air activity began, and automatic radiation-level alarms sounded in the reactor building. A phone call to the control room from the adjoining chemical extraction plant reported atmospheric activity off-scale and requested the emergency stay-in procedure. The sirens for this were sounded. The radiation hazards control branch got busy reading instruments, making surveys, and collecting reports.

Some minutes later the activity inside buildings with forced ventilation



NRX REACTOR

ATOMIC ENERGY OF CANADA LIMITED - CHALK RIVER, ONTARIO was found higher than outside; therefore on the advice of the Biology and Radiation Hazards Control Director the Project Head gave the order for the plant evacuation procedure, and that went into effect.

Meanwhile in the reactor system not earlier than 30 sec before the dumping began, helium began to leak at a rate of 140 cu ft/min. After 314 min, by which time the reactor power had been down to a negligible level for 2 min, the reserve gasholder was almost empty. Then suddenly in less than 30 sec the 585 cu ft gasholder rose to its fullest extent. The change of direction of motion of the gasholder was so abrupt on the record and its motion so well-timed by pen marks at 15-sec intervals that it can be deduced with certainty that within a period of 15 sec the gasholder became connected presumably to a mass of gas at high enough pressure to give a large acceleration to the massive gasholder."

The Power Surge

Although all relevant instruments went off scale, it proved possible to piece together data to construct reasonably well-timed curves of power and reactivity.

Before the first bank of shut-off rods was raised the reactor was more reactive than supposed owing to a number of shut-off rods not being down. This unsuspected extra reactivity was about 10 mk. Raising the first bank made the reactor overcritical by about 6 mk, and it diverged with a doubling time of about 2 sec, reaching a power of the order of 100 kw. At this point the reactor trip circuit opened, but only one shut-off rod fell slowly in. The reactor continued to diverge but at a rate decreasing with time in such a way as to suggest that it would have leveled off at about 20 megawatts.

At 17 megawatts on this scale boiling is presumed to have occurred in some of the temporarily cooled rods, expelling light water from the reactor and increasing the reactivity by at least 2 mk. The reactor continued to diverge for a period of 10 to 15 sec and reached a power between 60 and 90 megawatts when it was checked by opening the heavy-water dump valves and also possibly by ingress of light water through ruptures in the cooling-water tubes. Tentatively the power surge is taken as 4000 megawatt-sec."

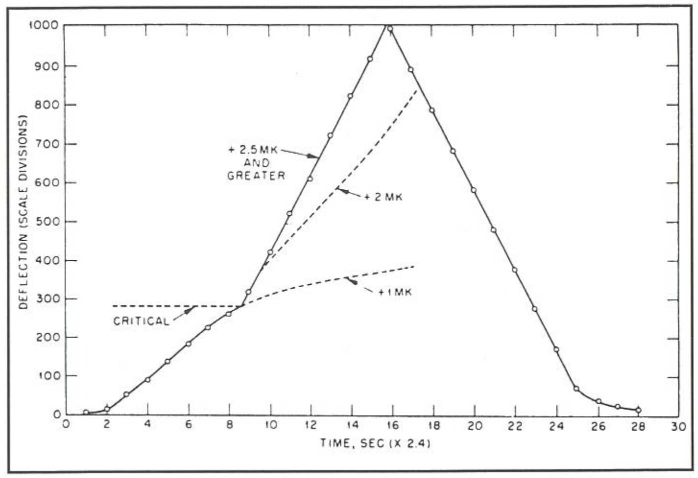


Figure 1: Expanded trace of power recorder during the power surge with transients from simulator superposed. (Time scale is in units of 2.4 sec., the interval between successive balancings.)
_______ , NRX transient. ----- , reactor simulator transient.

(from "A Reactor Emergency - with Resulting Improvements" by G. W. Hatfeld, AECL-164)

"It was not considered safe to shut off the flow of cooling water as the condition of the uranium was not known. The main concern was the fact that some of this uranium was highly irradiated and, if this uranium were not cooled, it would heat up to the point where the metal would oxidize rapidly and even catch fire. Therefore, as the first precaution, the cooling water to all the rods in the reactor was decreased to a minimum by gradually throttling the flow of water through the valves heading to the main header. In this manner the flooding of the basement was decreased from 300 to 60 gpm. This was followed later with shutting off the cooling water to the rods which were not ruptured after installing special headers. Here, needle valves were used to control the flow at the top and bottom of each ruptured rod. After this installation was completed the leak to the basement was decreased to 14 gpm.

At the same time, while we were endeavouring to decrease the flooding below the reactor, the active water which already had collected in the basement was being pumped to large storage tanks outside the main building and these tanks were rapidly becoming filled to capacity. A decision was made 5 days after the accident to pump this active water out to the disposal area where the soil was a mixture of sand and clay. In zero weather a pipe line 11/4 miles long with the necessary pumping facilities was installed in the next 5-day period. Approximately 1,000,000 gal of active water containing 10,000 curies of long-lived fission products were pumped through this pipe line to the disposal area. A check was kept on the activity in the water draining from the disposal area and no detectable activity has been found even in the creek draining this area to a small lake.

Dismantling the Reactor

It is difficult to describe the multitude of problems associated with radioactivity with which we were faced during the next 8-month period when dismantling the reactor. These problems included the design and fabrication of many special tools for use by remote control for cutting and removing the ruptured rods out of the reactor as well as the removal of the stainless-steel water headers and valves below the reactor which were badly contaminated, and the decontamination of thousands of square feet of concrete throughout the reactor building.

Removing the Aluminum Calandria.

The procedure used for removing the aluminum calandria from the reactor will be described. This calandria is probably the largest radioactive source that has been handled to date.

Owing to this high level of radioactivity, all operations had to be controlled remotely.

A lifting jig was first lowered down on top of the calandria. This jig had dogs hanging below, designed in such a way that when the dogs entered the holes through the calandria tube sheet, they slipped outward hooking onto the underside of the sheet when a lifting strain was applied to the jig. The overhead crane hook was lowered and engaged by remote control to the hook on the lifting jig. The calandria was then raised out of the hole and, with the use of long ropes as guides, it was moved across the pile by the crane and lowered into a canvas bag which was attached to a skid turned up on one end against the side of the reactor.

The skid was then lowered into a horizontal position on the floor of the reactor building by slackening off on a yoke which was attached from the outer face of the skid to the inner face of the reactor and thence out to a bulldozer which acted as a winch. After the skid was in a horizontal position on the floor, the pin was withdrawn from the outer end of the skid by means of a long rope attached. This released the skid from the yoke.

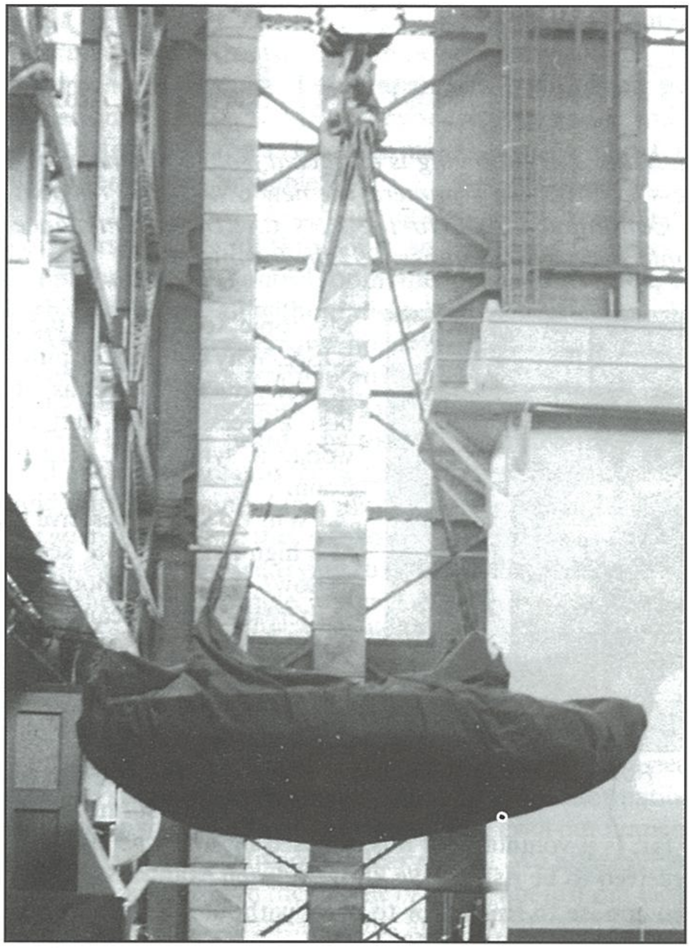
The skid was then towed out of the reactor building, with all remaining ropes attached, with the use of a grader, through the plant proper to the disposal area about 1½ miles away.

Radiation Measurements.

Radiation measurements on this tank indicated 20 roentgens per hr in contact with the top tube sheet, 100 roentgens per hr in contact with the side of the tank, and 300 roentgens per hr in contact with the bottom tube sheet.

Reconstructing the Reactor.

On reconstructing the reactor all of the equipment removed was decontaminated and used over again, such as shields, water headers, pipes, valves, instruments, and so on, with the exception of the aluminum tank and one steel shield immediately above the tank which were purposely damaged beyond repair in order to simplify the removal of the ruptured rods. These two pieces of equipment were replaced by new equipment."



Carefully swathed to provent the spread of radioactive contamination the thermal shield is lowered onto a skid during the dismantling of the NRX reactor following the accident of 12 December 1952.

How Others Saw It

Although there was fairly widespread media reporting of the NRX accident it was relatively subdued, especially in comparison to later events such as TMI and Chernobyl. This was partially due to the secrecy that still surrounded the Chalk River project at the time and partially to the different social environment of the period. The federal minister responsible for atomic energy program, C.D. Howe, announced that the reactor had suffered "a pin hole leak" which, apparently, was accepted by the press, at least initially.

Later there were some lurid accounts. Almost a year later the American magazine, Popular Science, ran an article about the removal of the calandria under the title, "An Atomic Dragon's Eerie Funeral." Following are some excerpts from that story.

"This is the story of a funeral the strangest funeral in the history of man. The coffin was a huge canvas bag, the grave a great hole and the mourners atomic scientists.

"The corpse was the [NRX] calandria - the largest and most dangerous radioactive object that has ever been handled.

[After the immediate handling of the accident] "the next step would be the dramatic operation of removing the calandria. The plan - an overhead crane would lift the tank (10 ft. high, 8 ft. dia.) out of the 35 foot-high reactor structure. Then the tank would be dropped into a huge canvas bag on a cradle. The cradle would be lowered to horizontal, onto skids, and towed away to a burial ground outside the [inner] plant.

"A long whistle blast warned that the funeral procession was underway. In buildings along the way pens of radiation monitoring instruments went off the charts.

"The [burial] ground will not go unvisited - but so formidable is this atomic dragon, even in death, that it will be perilous to approach for some time to come."

Bibliography

For those who would like to read more about the NRX accident, following are some relevant AECL reports:

AECL-232 The Accident to the NRX Reactor on December 12, 1952, W.B. Lewis

AECL-233 Accident to the NRX Reactor, Part II D.G. Hurst

AECL-164 A Reactor Emergency - with resulting improvements, G.W. Hatfield

AECL-83 Reconstruction of the NRX Reactor, J.L. Gray

AECL-590 An Appreciation of the Problem of Shut Off Rods with special reference to the NRX Reactor, W.B. Lewis, A.G. Ward

AECL-1877 Fission Product Release from the NRX 1952 Accident, W.J. Edwards

More history

The Montreal Laboratory

- the conception and birth of the Canadian nuclear program

Almost exactly 60 years ago, in early 1943, a group of British, European and Canadian scientists moved into a new but unused building on the campus of the University of Montreal to begin the work that would lead to NRX, ZEEP, Chalk River Laboratories, and eventually, the full Canadian nuclear program. The project was set up under the National Research Council and was soon called the Montreal Laboratory. Starting from a rudimentary knowledge of fission, behaviour of neutrons, radiation effects, and related matters, the group managed to develop the conceptual design of NRX by late 1944.

To provide some insight to this auspicious but largely unheralded achievement we present an extract from a talk given in 1966 to the Canadian Association of Physicists by George Laurence, at that time President of the Atomic Energy Control Board, who had been the senior Canadian at the Montreal Laboratory.

Laurence was born in1905 in PEI. On a scholarship to Cambridge University in the UK he studied at the Cavendish Laboratory under Lord Rutherford. Returning to Canada in 1931 he joined the National Research Council in Ottawa to head a new division of radiography. Following the discovery of fission in 1939 he, together with Bernard Sargent, over the summers of 1940 -42 and working in their spare time, built a sub-critical assembly of uranium oxide and coke, one of the first such experiments in the world. That work was an important factor in the decision, in 1942, by the British government to move its atomic research to Canada. The British team included a number of scientists who had escaped from the Nazi invasion of 1940 and who had brought heavy water spirited out of Norway just before that country was overcome.

A longer, more formal, paper by Laurence on the same subject entitled "Early Days of Nuclear Energy Research in Canada" was published by Atomic Energy of Canada Limited in 1980.

He began his talk with some reminiscences of his graduate days and then spoke briefly about the sub-critical assembly mentioned above.

We were still doing things by ourselves during those experiments which Dr. Sargent and I did in Ottawa with uranium and petroleum coke. With a few lab assistants, we loaded ten tons of the black powdery petroleum coke into a big bin. We arrived home looking like coal miners just emerging from the pit. We explained to our families that we were doing secret war work.

The neutron detector used in the first measurements was a twenty-five cent piece. Since the half-life of silver 109 is about twenty-four seconds, one had to step lively. The twenty-five cent piece was pulled out of the uranium and carbon lattice precisely on the minute - one rushed across the room to place it in front of the homemade geiger counter (taking care not to poke your finger through the thin glass window of the geiger counter) - and switched on the counting circuit at precisely twenty seconds after the minute. The counting was stopped at precisely one hundred and twenty seconds after the minute. Later we obtained some disprosium and were able to make a more accurate detector of disprosium which, of course, has a much longer half-life.

Many of you remember the Montreal Laboratory - the wartime atomic energy project in Montreal. Some of you will have read about it in one or more of the official histories of the early days of atomic energy development that have been written from different national points of view. At the risk of adding confusion, I thought it might be of interest to recall unofficial impressions of it.

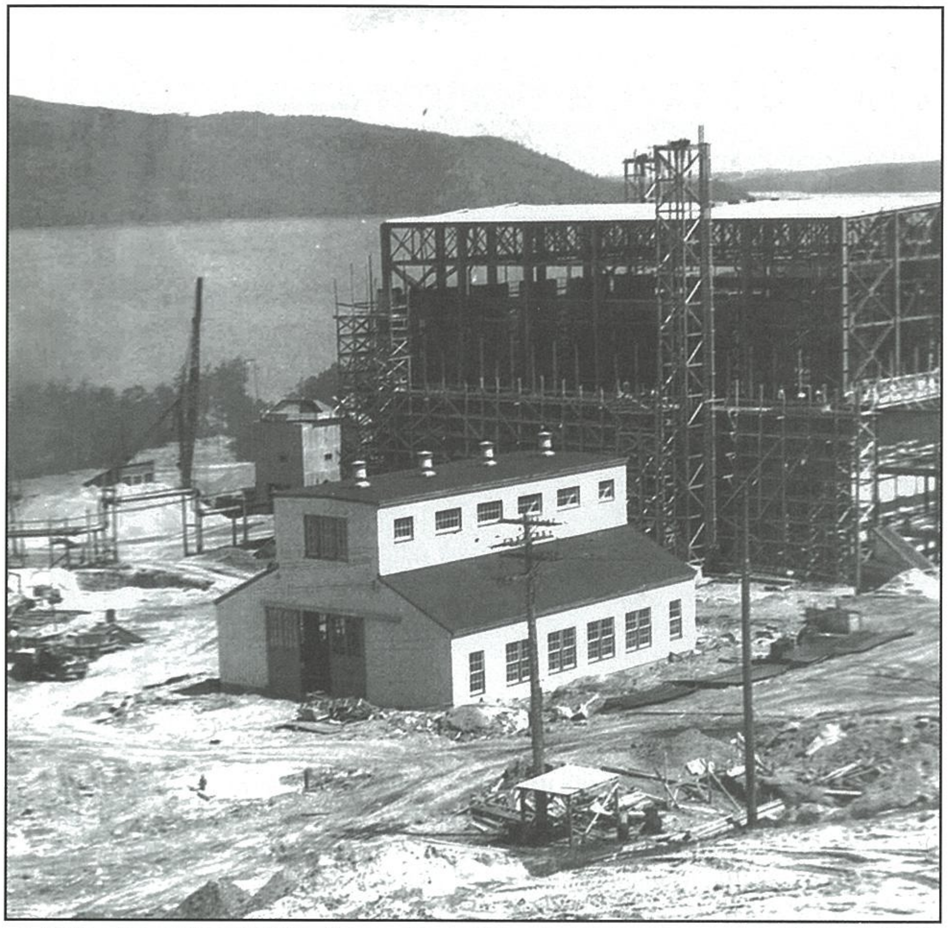
Early in 1942 the British decided that their research effort on atomic energy would be more effective if it were moved to the United States where the supply of equipment and materials was easier and where they could collaborate closely in the American programme. The Americans rejected this proposal. They felt that it was too great a security risk because the senior members of the group that would be sent from Britain were refugees from countries in Europe that were under Nazi domination.

The British then suggested that their team be moved to Canada where they would be closer to the American effort. The Americans could scarcely refuse to accept this arrangement. The proposal for a joint British-American-Canadian atomic energy research project in Canada was put to Dr. C. J.

Mackenzie [president of NRC] and then to the Honourable C. D. Howe [Minister of Munitions and Supply]. On September 2, 1942, Sir John Anderson formally asked for a reply.

The objective was speculative. It was doubtful if it could be completed before the end of the war. It would divert scientists, equipment and facilities from other wartime effort and would commit Canada to the expenditure of many millions of dollars. There would be difficulties in the procurement of materials, particularly the many tons of heavy water.

Dr. Mackenzie said later that the deciding consideration was the thought that when peace was restored atomic energy was bound to have consequences of social and economic significance far beyond the possibilities of imagination and prediction, and that the proposed United Kingdom-Canadian research effort would provide an opportunity for the training of Canadian scientists in this field that should not be missed. So the decision was made.



A 1945 view of the ZEEP building. The building behind, under construction, is NRX.

It was decided that administration of the laboratory would be under the National Research Council. It would be in Montreal, and Hans H. von Halban, who was the leader of the group in Britain, would be the scientific director of the laboratory.

By the end of the year 1942 the first of the British team had arrived from England. It consisted of two Frenchmen, two Germans, one Czechoslovakian, one Austrian, an engineer from Imperial Chemical Industries, and one other Englishman. As temporary quarters, we occupied an old residence, later torn down, at 3470 Simpson Street in Montreal, and as we recruited more staff it became very crowded. The master bedroom served as the director's office while the adjoining bathroom was occupied by his secretary as her office.

Three months later [early 1943] we moved into larger space in the new building of the University of Montreal. Dr. [David] Keys, acting on behalf of the Wartime Bureau of Technical Personnel, helped us in finding Canadian scientists and engineers. More scientists and engineers came from the United Kingdom and the staff grew fairly quickly to over 300.

The project was started in an atmosphere of enthusiasm and expectation of great scientific adventure. Technicians were soon busy making boron chambers to detect neutrons and scaling circuits to count them. Twenty tons of graphite bars were obtained and Dr. Sargent and other physicists were measuring the penetration of neutrons through that material. A two million volt X-ray machine was purchased and its rays, by bombarding beryllium, provided a source of neutrons for experiments in the graphite.

About one hundred kilograms of heavy water arrived from England. It was a major part of the world supply at that time which the French scientists von Halban and Lew Kowarski were able to get out of France before it was overrun by the Germans. This was a precious treasure. Great care was taken to avoid loss of even minute quantities by evaporation. Drips were carefully wiped up with hospital cotton which was then sealed in vapour-tight containers so that the heavy water could be recovered.

The theoretical physicists, among them George Volkoff and other Canadians, were busy developing mathematical methods for the calculation of the behaviour of neutrons in an atomic reactor. The chemical properties of uranium, neptunium and Plutonium were being investigated and efforts were made to develop a corrosion resistant alloy of uranium. The biological effects and the hazards of radiation were being studied.

Various kinds of reactors were discussed and considered. One proposal was that the uranium should be in the form of a slurry in heavy water. I remember footprints down a corridor - yellow footprints. Someone had spilled some "mayonnaise" and stepped in it. "Mayonnaise" was the

This rare photograph from the Montreal Laboratory shows mostly members of the Physics Division in late 1943.
Counter clockwise from front left: Warwick Knowles, Dr. Pierre Demers, James Leicester, Dr. Henry Seligmann, Ernst Courant, Ted Hinks, Fred Penning, Dr. Bruno Pontecorvo, Dr. George Volkoff, Dr. G. Placzek, (U.S. Liaison Officer), Dr. Allan Nunn May, Quenton Lawrence, Stefan Bauer, Dr. George Laurence, Dr. Pierre Auger, Dr. (Sir) John Cockcroft, Frank Jackson, Newell, Dr. H. Von Halban, H.F. Freundlich, Dr. Jules Gueron (Chemistry Division), Gordon A.R. Graham, Dr. B.W. Sargent, John Ozeroff, Dr. Bertrand Goldschmidt (Chemistry Division), Alan Munn

laboratory jargon for a slurry of uranyl nitrate in water. That was before there were any regulations about radioactivity contamination.

Soon we became impatient as we waited for the close collaboration with the Americans to become established. The Americans were still worried about safety and the very mixed national background of our team. They made counter proposals for a limited cooperation for the exchange of information restricted to certain aspects of the work only. In particular they excluded information on the chemical extraction of plutonium on the grounds that the supply of this information to Montreal would not in any way contribute to the war effort at that time. They would agree that certain British scientists of outstanding reputation, such as Oliphant, could work in the United states on certain specific aspects of the undertaking, but their travel would be restricted and they would not meet with certain senior United States scientists.

The British felt that the attitude of the Americans was unfair and somewhat insulting. This British reaction was not understood in the United States and the Americans seemed to be offended when their proposal was not accepted. To Canadians it seemed particularly frustrating and tragic that there should be such poor understanding between the British and the Americans.

Meanwhile the Montreal Laboratory was cut off from information about the atomic energy work in the United States. This was in contrast to the easier correspondence that had existed before. In 1941 I had visited Columbia University where I talked to Fermi, Compton and Pegram, who described their sub-critical experiments with graphite blocks and uranium, and to Urey who discussed the production of heavy water and the separation of U-235. In Washington I talked to Dr. Briggs, the chairman of the committee that was then coordinating the atomic energy research in the United States. In 1941 and 1942 we obtained secret reports of the American work without difficulty.

Our Director was of a family that might be described as belonging to the lesser nobility in Austria. He had come to Canada happy in the expectation that it would be much easier to secure materials and supplies for the laboratory than it had been in Britain under the blitz. However, in 1943, supply in North America was becoming difficult. I can remember angry phone calls to Ottawa to the National Research Council's Purchasing Department. Where was his waste basket? It was to have been delivered weeks ago.

von Halban was not accustomed to Canadian business methods. The administrative staff in Ottawa was equally unaccustomed to the Austrian lesser nobility. They spoke of the Montreal Laboratory as a madhouse - not an ordinary madhouse, but one that was run by the inmates.

The Director's criticism of the Purchasing and other administrative divisions of the National Research Council in Ottawa was echoed by some of the other staff members from abroad who were not really in a position to know, and has some reflection in one of the official histories. This is most regrettable because it was unjust to a very capable staff that worked hard to provide a service to the Montreal Laboratory in spite of the demands on their energies of other war work that was more urgent and more important.

In the beginning it was intended that the scientific programme of the laboratory should be planned by a committee known under the code name of the Technical Committee on Radiological Protection. The committee soon ceased to meet and I, as the only Canadian on it, was left more and more in the dark about what was being planned. This was just another aspect of the difficult relations between the scientific direction of the laboratory and the National Research Council.

[British Prime Minister Winston] Churchill discussed the very unsatisfactory state of British-American collaboration in atomic energy with [US President Franklin D.] Roosevelt at the Quebec Conference. On August 19, 1943, they agreed on behalf of their governments that arrangements would be made "to ensure the full and effective collaboration between the two countries in bringing the project to fruition."

Notwithstanding this, months passed without progress towards effective collaboration. The morale of the Montreal Laboratory sank very low.

It was generally believed by the Montreal scientists that it was General Groves, who had charge of the whole American effort [Manhattan Project], that was responsible for the delays. It seems clear now that it was senior American scientists, Vannevar Bush and J. B. Conant, that dragged their heels. Both in the United Kingdom and the United States the situation was worsened by poor communication between heads of state, officials and scientists, and it resulted in errors in judgment and misunderstandings between the two countries. By the end of 1943 the usefulness - at least for Canada - of continuing to operate the laboratory was questioned. There appeared to be too little point in it unless effective collaboration could be established.

Those who played leading parts in the negotiations at this time were General Groves, Professor [Sir James] Chadwick and Dr. Mackenzie. Groves and Chadwick were men of very different backgrounds and temperament: one a blunt soldier and tough administrator; the other, as you know, a sensitive scientist. Yet, evidently a mutual respect and confidence had grown between them. This factor, as well as the good sense of the three men, made it possible at length to bring about cooperation and thus to save the Montreal Laboratory.

John Cockcroft was persuaded to become Director of the laboratory and it was agreed that the alien members of the staff should leave. It was agreed to proceed at once with a heavy water moderated reactor plant in Canada, The atmosphere changed quickly. The Americans then whole heartedly supported the project. Scientific information, essential supplies and help in many ways came from the United States and visits were arranged for senior Montreal scientists to the American projects.

Defence Industries Limited was engaged to do the engineering design of the laboratories, reactors, services, and the townsite. Fraser-Brace Limited would do the construction. A much less powerful reactor, which became known as "ZEEP" was built first to test certain features of the design of the larger reactor NRX.. Under Cockroft's direction, administration became less difficult and a sense of purpose was restored to the Montreal Laboratory. As laboratories were built in Chalk River and houses for the staff in Deep River, the Montreal Laboratory was gradually closed down.

Secrecy was an important feature of the whole activity with great precautions for the care of documents and detailed instructions to the staff regarding what they might discuss with their colleagues in other divisions of the laboratory, and what they might write on blackboards that were opposite windows. It sometimes was carried to childish extremes. For example, in chemical formulas uranium was represented by the letter X.

On one occasion we received a visit from the United States by a Mr. Baker. Senior members of the staff and their wives were entertained at Cockcroft's home. All evening we chatted with Mr. Baker, solemnly addressing him by that name, but knowing all the time that he was Neils Boar.

In spite of the administrative difficulties, the lack of clearly defined objectives, and the sense of disappointment and frustration during the period of about a year, the scientists in the Montreal Laboratory maintained a very high standard in their research.

I would like to mention the names of some of the Canadian physicists who participated in this work.

Jeanne L. Agnew; D. S. Craig; p. Demers; D. G. Douglas; L. O. Elliott; S. C. Fultz; Q. A. Graham; E. Guptill; T. J. Hardwick; E. P. Hincks; D. O. Hurst; D. Kirkwood; W. J. Knowles; S. A. Kushneriuk; M. W. Lister; J. C. Mark; A. M. Munn; J. W. Ozeroff; B. W. Sargent; J. D. Stewart; Miss A. Underhill; D. Van Patter; E. B. Paul; O. M. Volkoff; P. R. Wallace; W. H. Walker; A. O. Ward.

In addition, the following, who were members of the British staff in Montreal, became Canadian residents:

C. B. Amphlett; H. Carmichael; B. Davison; K. D. George; R. G. Hanna; J. F. Steljes; J. B. Warren; C. H. Westcott.

Besides those whose names I have read, there were, of course, the physicists from other countries and the specialists in other sciences and engineering. Never before in Canada had so large a group of scientists of different disciplines been brought together for a single purpose.

Their work in the Montreal Laboratory was mostly applied research but the background of most of them was fundamental research. Canada's atomic energy had its origin in fundamental science, and, through wise direction at Chalk River, fundamental science has continued to inspire and stimulate it.

Never before has the Government of Canada supported so strongly a specific programme of research and development. The consequential growth of our nuclear industry is one of the factors that has brought about a growing realization that strong support of research is essential in a country that aspires to compete as a manufacturing nation in the commerce of the world.

The Montreal Laboratory and the research and development that has since grown from it have brought Canada recognition as one of the pioneer nations in atomic energy, have given greater authority to Canadian opinion in international relations, and have opened greater opportunities for us in industry and commerce. The Montreal Laboratory is deserving of mention in the history of science in Canada.

GENERAL **news**

USA and China join ITER

At the end of January U.S. Secretary of energy, Spencer Abraham, announced that the USA is rejoining the Iter international fusion project.

"This international fusion project is a major step towards a fusion demonstration power plant that could usher in commercial fusion energy," Secretary Abraham said. "ITER also provides a cost-effective way to proceed with fusion research worldwide with the collaborating parties sharing in the project's cost of construction and operation." Secretary Abraham made the announcement January 30, 2003, during remarks to employees of the department's Princeton Plasma Physics Laboratory

The U.S. proposes to provide a number of hardware components for ITER construction, to be involved in the project construction management and to participate in the ITER scientific research and technology development. The nature and details of the U.S. participation and contributions would be determined during the negotiations. DOE's Office of Science, which has extensive experience in large, international programs, will lead U.S. negotiations on ITER.

The construction cost for ITER, including buildings, hardware, installation and personnel, is estimated to be about $5 billion in constant 2002 dollars. However, since the cost will be shared among all of the parties, who will provide most of the components "in kind," the actual construction cost will be a combination of different amounts in different currencies. The U.S. share of the construction cost is expected to be about 10 percent of the total. ITER could begin construction in 2006 and be operational in 2014. Fusion research would last for up to 20 years.

The Department of Energy commissioned three reviews of ITER in preparation for a Presidential decision on whether the U.S. should enter into negotiations on participation in the ITER project. A National Research Council report endorsed the ITER effort as an essential next step in the U.S. fusion energy research program.

Earlier in January the Minister of Science and Technology of China, Mr. Xu Guanhua, wrote to the four heads of delegation in the Iter negotiations requesting that China participate. He stated that China intends to provide a substantial contribution to the project, comparable to that envisaged by other participants.

An administrative delegation of the Iter Negotiators visited Beijing in November 2002 and a Chinese delegation visited the Garching, Germany facility in December. The team visiting China stated that the equipment and methods there were comparable to those in more developed countries.

The Iter Negotiators met in Spain in early December 2002 and again in St. Petersburg, Russia, February 18 and 19, 2003. The final report of the Joint Assessment of Specific Sites was scheduled to be tabled at the latter meeting. Iter Canada has submitted a modified bid as a result of developments since it was first submitted in 2001. A decision on a site is scheduled for this coming summer.

AECL partners with Bechtel in USA

In December 2002, Atomic Energy of Canada Limited (AECL) and Bechtel Corporation of the USA announced an agreement for the two companies to work together on the deployment of the Advanced CANDU Reactor in the USA.

The two companies will establish a project team in Bechtel's Frederick, Maryland office for the deployment of the ACR in the U.S. According to AECL's president Robert Van Adel, the agreement brings together AECL's expertise as an innovative technology developer and international project manager with Bechtel's premier architect/engineering and project management skills.

The ACR is AECL's new design based on the well-proven 700 MWe class CANDU nuclear power plant. It is planned to be priced competitively with other forms of electricity generation and to have a 36-month construction schedule. The ACR is currently in Pre-application Review with the U.S. Nuclear Regulatory Commission (NRC) and has a parallel licensing track in Canada with the Canadian Nuclear Safety Commission (CNSC).

Bechtel president James Reinsch stated that, "AECL and Bechtel have had a successful project with the construction of two CANDU 6 reactors at the Qinshan Phase III site, China. The new ACR agreement is seen as a logical extension of this existing relationship."

MAPLE commissioning continues

The low power commissioning of the MAPLE 1 reactor at Chalk River and the fuel loading of MAPLE 2 were reported at the hearing of the Canadian Nuclear Safety Commission, January 16, 2003. This was the first day of the CNSC standard two-day hearing system for an operating licence for the two small reactors being built by Atomic Energy of Canada Limited for MDS Nordion. They will be dedicated to the production of radioisotopes for medical applications.

The MAPLE 1 reactor was operating at 2 kw, a CNSC "hold point". Specific authorization is required from CNSC staff to exceed that level and subsequent "hold points" at 500 kw and 8 Mw.

At the January 16 hearing CNSC staff stated that their review of the MAPLE reactors and associated isotope processing facility was being integrated with the review for renewal of the licence for the entire Chalk River site. CNSC staff stated that the most pressing outstanding issues pertained to quality assurance.

The second day of hearing for both the MAPLE project and the CRL licence will be held April 9, 2003.

Bruce Power completes new financing

On February 14, 2003, Bruce Power announced the successful financial close of a deal that sees two more Canadian-based companies join the Bruce Power Limited Partnership, allowing British Energy plc to relinquish its entire 82.4% stake.

TransCanada PipeLines Limited of Calgary and BPC Generation Infrastructure Trust of Toronto have teamed with Cameco Corporation of Saskatoon to buy 79.8% of Bruce Power L.P. from British Energy. The Power Workers' Union (PWU) and The Society of Energy Professionals (The Society) have assumed British Energy's remaining 2.6% share, increasing their equity stake to a combined 5.2%.

Under the revised partnership, Cameco has more than doubled its original stake in Bruce Power to 31.6%. TransCanada and BPC Generation Infrastructure Trust, a trust established by the Ontario Municipal Employees Retirement System, will also hold 31.6% stakes, while the PWU will own 4% and The Society 1.2%.

The consortium has also assumed British Energy's financial assurance obligations to Bruce Power regarding its Canadian Nuclear Safety Commission (CNSC) licence and the power purchase agreements with customers. As well, the consortium has acquired British Energy's 50% interest in Huron Wind, Ontario's first commercial wind farm. A partnership with Ontario Power Generation (OPG), Huron Wind's five 1.8 MW turbines are located on land adjacent to the Bruce Power Visitors' Centre.

Having already received CNSC approval for its Environmental Assessment of the Bruce A restart project, Bruce Power will appear before the commission on Feb. 26 for Day 2 of its licensing hearing. Pending regulatory approval, Bruce Power intends to return Bruce A Unit 4 to service by the end of April, followed by Unit 3 before this summer's period of peak demand.

On February 11, 2003, a panel of the CNSC held a closed meeting to consider the acceptability of the financial guarantees proposed by Bruce Power Inc. in anticipation of the sale by British Energy plc of all its interests in Bruce Power Inc. and Bruce Power LP to Cameco Corporation, TransCanada Pipelines Limited and BPC Generation Infrastructure Trust. Based on its consideration of this matter, the panel found that the new financial guarantees are in a form acceptable to the Commission for the purposes of condition 11.3 of the Bruce "B" licence.

Application Of Nuclear In Oil Sands Studied

The Canadian Energy Research Institute (CERI) has been contracted by Atomic Energy of Canada Limited (AECL) to conduct an economic study of the potential application using the Advanced CANDU Reactor in the extraction of oil out of tarsands.

There has been a considerable amount of interested comment from media in Alberta and Saskatchewan. The Saskatoon Star-Phoenix commented, "Building these power plants in Saskatchewan would be a tremendous boost to a critical industry just as the world is looking for alternative energy sources." Further on, speaking about Canada's nuclear industry, the paper noted, "Although critics have voiced concerns for decades, the most serious problem that can be attributed to the industry is the vocal-chord damage done to those warning of our imminent doom."

The Edmonton Journal questioned whether burning natural gas to extract oil was the best use of a fuel that has many other applications. It endorsed the statement of Alberta Environment Minister Lome Taylor that nuclear power has some advantages but that the question of nuclear waste disposal is not yet resolved.

The CERI cost-benefit study is expected to be completed by the end of March 2003.

Bruce 4 refuelling underway

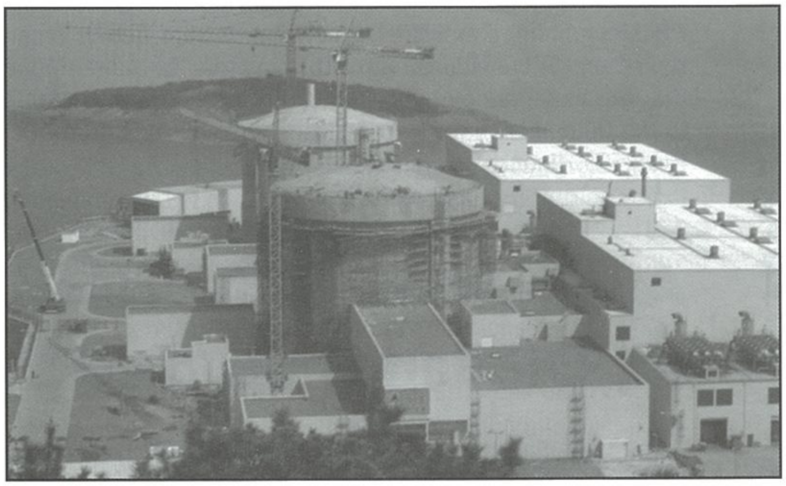
Bruce Power begun refuelling Unit 4 at the Bruce A generating station in mid January 2003 after receiving permission from an officer designated by the Canadian Nuclear Safety Commission (CNSC) to start the next phase of the Bruce A Restart project.

Bruce Power crews began loading fuel into Unit 4 on January 14 after the CNSC certified the team of Shift Supervisors and Nuclear Operators who will be responsible for the two Bruce A units in what is known as a Guaranteed Shutdown State with New Fuel.

It will take about 45 days for an enormous fuelling machine to install 6,240 fuel bundles into 480 fuel channels on the reactor face. When refuelling is complete on Unit 4, employees will turn their attention to Unit 3. Pending further regulatory approvals, Unit 4 could be returned to service by April, followed by Unit 3 before this summer's period of peak demand.

In early January, the CNSC accepted the company's Environmental Assessment Screening Report, ruling that the restart of Units 3 and 4 is not likely to cause significant adverse environmental effects. Bruce Power appeared before the CNSC January 16 for the first day of hearing on its Bruce A Restart project. The second day is scheduled for February. 26.

Unit 4 first went into service on Jan. 18, 1979, but was laid up on March 16, 1998 by the previous operators of the Bruce site. Unit 3 went into service on Feb. 4, 1978 and was laid up on April 9, 1998. All of the systems necessary to safely control and monitor the reactor in its fuelled state had already been returned to service in preparation for fuel loading.



Qinshan I in commercial service

The first CANDU unit at Qinshan, China, began commercial operation on December 31, 2002. The utility, The Third Qinshan Nuclear Power company, provisionally accepted the reactor on January 5, 2003. This was 38 days earlier than scheduled. The two unit project continues to be ahead of schedule and on budget.

Obituary

We deeply regret that the following note was inadvertently omitted from the last issue of the CNS Bulletin.

Peter Barnard

Peter Barnard, the founder and CEO of Iter Canada, died August 29, 2002 at the age of 64.

Peter founded Iter Canada in 1997 and was the driving force behind the project. He garnered support from government, utilities, industries and communities to build a team to bring the international Iter fusion project to Canada. Iter Canada was the first to propose a site for the hugeinternational project, at Clarington, Ontario, next to the Darlington NGS of Ontario Power Generation.

Peter was born in Montreal in 1938 but moved to Oakville where he became a star quarterback at Oakville Trafalgar High School. He studied civil engineering at Queen's University and obtained a Ph.D. from Cambridge University, where he was also captain of the Cambridge ice hockey team. Subsequently he attended Harvard Business school and at the age of 28, founded his own management consulting firm, Peter Barnard Associates. Over the next 20 years the firm grew to 25 staff before merging with a multi-national company now called Boston consulting Group. In the early 1990s he was appointed chairman and CEO of the Canada's largest management consulting firm, KPMG Peat Marwick Stevenson and Kellogg. He also served as chairman of Ontario Hydro Technologies between 1994 and 1997.

He leaves his wife Despina and sons Robert and Christopher.

The Council of the Canadian Nuclear Society voted to donate $500 to the Peter Barnard Memorial Fund which has been set up to support his favorite organizations, Cambridge University, Canadian tennis and the town of Creemore.

Canadian Nuclear Society
Société Nucléaire Canadienne

Co-Sponsored by
International Atomic Energy Agency
Agence Internationale de l'Énergie Atomique

8th International Conference on CANDU Fuel
Delawana Inn, Honey Harbour, Ontario, Canada
2003 September 21-24

CALL FOR PAPERS

The Canadian Nuclear Society (CNS) cordially invites you to submit a paper for the Eighth International Conference on CANDU Fuel, to be held at the Delawana Inn in **Honey Harbour, Ontario, September 21-24, 2003**. This conference will bring together designers, engineers, manufacturers, researchers and modellers to share the wealth of their knowledge and experience. The previous conference in 2001 produced an excellent selection of high-quality and well-received papers.

Paper Categories

A. **Fuel Performance:** Station experience, Post-irradiation examination (PIE) studies/techniques, fuel behaviour (normal operating conditions and extended burnup);

B. **Fuel Safety:** Licensing issues, accident analysis, fission-gas release, fuel behaviour and experimental simulation;

C. **Design and Development of Fuel and Fuel Cycles:** Modifications to designs, quality assurance in fuel design and development, MOX, inert matrices, Direct Use of PWR fuel In CANDU (DUPIC), slightly enriched uranium, recovered uranium, Thoria cycles, CANFLEXô, low -void reactivity, environmental, economical and societal implications of fuel cycles;

D. **Fuel Model Development:** Predictive capability on thermal, mechanical, irradiation and fission-gas-release behaviour under either normal operating or accident conditions;

E. **Manufacturing & Quality Assurance:** Fuel manufacturing experience, advances in manufacturing & inspection technologies and quality assurance;

F. **Fuel Management:** Fuel management schemes, load following, fuel physics analysis and operational problems;

G. **Fuel Bundle Thermalhydraulics:** CHF and CCP assessments, reactor aging, crept pressure tube and fuel simulations;

H. **Spent Fuel Management:** Handling technology, spent fuel storage and disposal approaches, in-storage fuel behaviour;

I. **History of CANDU Fuel:** Developments of CANDU fuel from design, testing and manufacture viewpoints, implementation of manufacturing quality assurance standards, development of fabrication technologies for CANDU fuel, and development of computer codes demonstrating fuel performance.

Paper Submission

Interested authors should submit a 500-word summary indicating the planned content for the session chosen from the above list. Summaries must be received by **2003 March 31.** Authors will be notified of the acceptance of their summaries by 2003 April 30. Camera-ready, **final manuscripts are required by 2003 July 30**. All accepted papers would be printed in the conference proceedings. Submit your summary either in electronic form (WORD) to andersb@aecl.ca, or in hard-copy to:

Brock Sanderson
Fuel and Fuel Channel Safety Branch
AECL, Chalk River
Ontario, Canada K0J 1J0
Tel: (613) 584-3311 ext. 3368 Fax: (613) 584-4200

CNS news

BRANCH ACTIVITIES

Chalk River Branch - *Michael Stephens*

On December 16, 2002, Keith Bradley (AECL Director, Asia-Pacific Market) spoke on "CANDU in China: Fuelling the Dragon".

At a special session January 16, 2003 the Branch donated the climate-change book "Taken by Storm" (by Christopher Essex and Ross McKitrick), to the W.B. Lewis Library in Deep River, with media coverage. *(See photo)* The same evening the Branch also donated a video containing the 1963 Crawley Films documentary on NPD, plus coverage of Lorne McConnell's evening address and the plaque ceremony itself from the NPD celebration in June 2002.

On January 30 Fred Boyd spoke on "The Birth of the Nuclear Industry", at an event co-hosted with the Algonquin Chapter of the PEO.

Coming up on February 20, Prof. George Bereznai will speak on the new University of Ontario for Industry and Technology.

Pickering Branch - *Marc Paiment*

On January 21, Dr David Torgerson, senior vice-president of Atomic Energy of Canada Limited made a presentation on AECL's Advanced CANDU Reactor (ACR) to a packed house at the Pickering Energy Information Centre Auditorium. (See photo) The more than 100 attendees were first given some insight into the role nuclear power may play in the evolving global energy supply/demand picture, followed by some more detail on the evolution of the ACR design from past CANDU plants. The follow-up questions were numerous and insightful - overall this was a resounding success.

Upcoming events include a talk by Dr Jerry Cuttler on the Beneficial Effects of Radiation, and a presentation by Dr Murray Stewart on the current status of Canada's bid for the Iter project.

We've now populated the CNS Pickering Branch link (on the CNS website) with some basic information on Branch events and contact information. Please have a look - suggestions on seminar topics and website ideas are welcome.

Ottawa Branch - *Bob Dixon*

The Ottawa Branch began the 2002 - 2003 season with a talk by Prof. Don Wiles on the Chemistry of Waste Disposal on October 3

On November 21 a good sized crowd braved bad weather to hear Dr. Romney Duffey, AECL Principal Scientist, give a detailed description of the Advanced CANDU Reactor design.

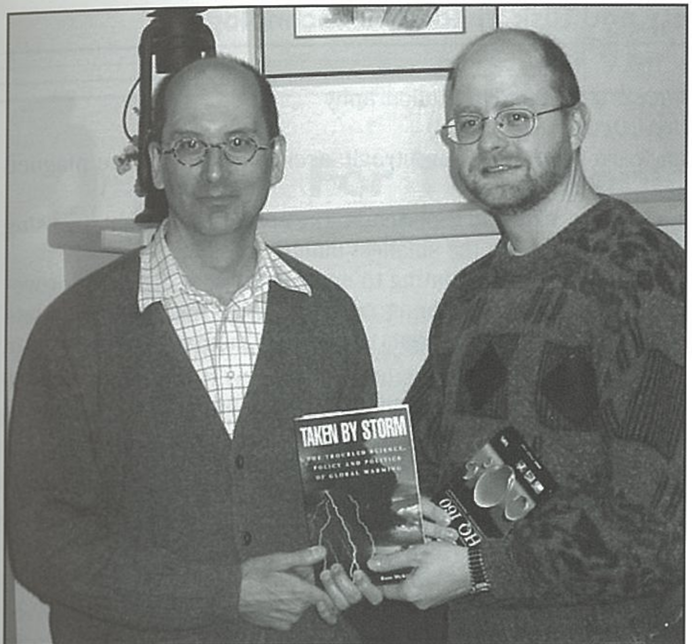
In the new year Geraldine Underdown, Director General Nuclear Safety with the Department of National Defence, is slated to speak on "Nuclear Safety and DND" on February 27 and Ken Talbot, vice-president of Bruce Power, is scheduled for March 19.

Again this year the Ottawa Branch will be supporting and offering a prize at the Ottawa Regional Science Fair to be held March 15.

Saskatchewan Branch - *Walter Keyes*

Nuclear power recently became a news headline in Alberta and Saskatchewan in the context of providing an energy source for heavy oil extraction in northern Alberta. *(See note in General News)*

As a result the Saskatchewan Branch of the CNS has briefed several groups on nuclear issues and participated in radio events. There seems to be a high level of public misinformation about solutions for spent nuclear fuel and the Saskatchewan Branch is attempting to organize one or two public seminars to inform the public on this matter.



Jeremy Whitlock, of the CNS Chalk River Branch, presents a copy of the book "Taken by Storm", toTom Wiwcharuq of the W. B. Lewis Library in DeepRriver, at a special event January 16, 2003

David Torgerson speaks to a full house at a special CNS lecture at Pickering NGS, January 21, 2003

CNS events in 2003

Thanks to the efforts of many volunteers the Canadian Nuclear Society will be hosting a number of events in 2003.

First is the **CANDU Chemistry Course** being held again at the offices of Babcock and Wilcox in Cambridge, Ontario. on February 17 and 18. This course was a repeat of the popular one run last year in the same location. This course is again organized by Bill Schneider.

On April 7 to 9 there will be another **CANDU Reactor Safety Course** being held this time at Sheridan Park, Mississauga. For last minute information contact Dorin Nichita at AECL Sheridan Park, tel. 905-823-9060 x 2221, e-mail: nichitae@aecl.ca

In June there is the **24th CNS Annual Conference**, the one major nuclear conference in Canada, and the embedded **28th CNS/CNA Student Conference**. This major event is being held at the Marriott Hotel Eaton Centre in Toronto from June 8 to 11. Contact the CNS office for more details.

The organizers of the **8th International Conference on CANDU Fuel** have chosen a resort location, the Delawanna Inn, Honey Harbour, Ontario. (Honey Harbour is on Georgian Bay about 150 km north of Toronto) This event will be held September 21 to 24, just after the peak of the tourist season. The deadline for submission of summaries is March 31. Contact Brock Sanderson , AECL Chalk River, tel. 613-584-8811x3368 e-mail: sandersb@aecl.ca. For general information or to register contact the CNS office.

November 16 to 18 are the dates for the **6th International CANDU Maintenance Conference** which will be held again at the Holiday Inn on King in Toronto. The past two conferences on this subject drew large attendances, reflecting the importance of maintenance in the safe and efficient operation of nuclear power plants. Contact the CNS office for further information.

Last notice / Dernier avis

Last notice to members who have not yet renewed their CNS membership for 2003:

Your membership is important to us and we do not want to lose you. If you do intend to renew, please take a moment to do so now – your membership expired December 31. Please communicate with the CNS office by telephone (at 416-977-7620) or by e-mail (at cns-snc@on.aibn.com) to arrange for your renewal. Or, if you still have the individual renewal form which was mailed to you in October, please fill it out and return it to the CNS office. If we do not hear from you very soon, we will unfortunately have to assume that you do not wish to renew. If you have already sent us your renewal form in the last few days, thank you!

Dernier avis aux membres n'ayant pas encore renouvelé leur adhésion à la SNC pour 2003:

Nous espérons vraiment ne pas vous perdre comme membre. Si vous comptez renouveler votre adhésion, veuillez prendre un petit instant pour le faire tout de suite – votre adhésion est échue le 31 décembre. Veuillez communiquer avec le bureau de la SNC par téléphone (au 416-977-7620) ou par courriel (à cns-snc@on.aibn.com) pour renouveler. Ou bien, si vous avez toujours le formulaire individuel qui vous a été envoyé par la poste en octobre, veuillez le remplir et le renvoyer au bureau de la SNC. Si nous n'avons pas de vos nouvelles très bientôt, nous devrons malheureusement conclure que vous ne voulez pas renouveler. Si vous nous avez envoyé votre formulaire de renouvellement ces derniers jours, merci!

Ben Rouben – Chair, Membership Committee/Président du comité des adhésions

BOOK REVIEW

Learning from Errors and Accidents: Safety and Risk in Today's Technology

by Romney Beecher Duffey and John Walton Saull
Hardcover: 224 pages, with colour illustrations, plus index, sources, and bibliography
Butterworth-Heinemann; ISBN: 0750675969; 1st edition (October 18, 2002)

The stated aim of this text is to show us how we can learn from errors and tragic accidents which have plagued our developing technological world.

It presents a concept and theory of how errors can be analysed to account for learning and experience. The authors show that, by using a universal learning curve, errors can be tracked and managed so that they are reduced to the smallest number possible.

The two authors have devoted a number of years to gathering data, analysing theories relating to error reduction, design improvement, management of errors and assignment of cause, related to millions of errors. The book explores many headline accidents from the Titanic to Chernobyl, Bhopal to Concorde, the Mary Rose to the Paddington rail crash to highlight human weaknesses in harnessing technology and examines errors over which we have little or no control.

By analysing the vast amount of data society has collected, the authors show how the famous accidents and our everyday risks are related. A number of nuclear related incidents are discussed and placed in the same context.

The authors compare their findings to the recorded history of tragedies, disasters, accidents and incidents in chemical, airline, shipping, rail, automobile, nuclear, medical, industrial and manufacturing technologies. They also address the management of quality and losses in production, the search for zero defects and the avoidance of personal risk and danger. The importance of a learning environment for safety improvement is stressed.

About the Authors

Romney Duffey is presently Principal Scientist with Atomic Energy of Canada Limited. He has written over 140 papers and articles. Educated in England, he has over 30 years of international experience in the UK, USA and Canada of technological safety and risk assessment, system design and safety analysis. He is Member of the American Society of Mechanical Engineers, and presently is Chair of the Nuclear Engineering Division, an active Member of the American and Canadian Nuclear Societies, and a past Chair of the American Nuclear Society Thermal Hydraulics Division.

John Saull is presently the Executive Director of the International Federation of Airworthiness after many years with the UK Air Registration Board and the UK Civil Aviation Authority, where he was Chief Surveyor and Head of Operating Standards. With over 40 years of experience of commercial aircraft certification, manufacturing, operations and maintenance, he is a leading expert in safety management and human error. He is an expert on maintenance practices and human error. He is a Council Member of the Royal Aeronautical Society and a Freeman of the City of London and Freeman of the Guild of Air Pilots and Navigators.

The book is available in Canada from your local independent bookstore, or on the web via www.amazon.ca. (Note: it is not listed in or carried by Indigo/Chapters/Coles, etc. in Canada.)

BOOK REVIEW

Creating the New world

by Theodore Rockwell
1st Books Library, Bloomington Indiana
Paperback ISBN 1-4033-9087-8 $19.50 (US) direct from publisher or author
Author's website: < members.authorsguild.net/tedrockwell >

Theodore Rockwell is the author of The Rickover Effect, an acclaimed account of the influence of Admiral Rickover the pioneer of the US nuclear navy.

In this book he tells the tale of those who worked at the Oak Ridge Laboratory in the days of the Manhattan Project and early post-war period. It describes the efforts to transform Oak ridge from a military project to an encompassing research centre.

Publications available

A Professional Assignment for Peace and Development

International Atomic Energy Agency
This brochure provides information on the possibilities for employment as a professional staff member of the IAEA.
It is available through the IAEA website: < www.iaea.org >
Public Access to Information held at the CNSC
DRAFT Regulatory Policy C-287

Canadian Nuclear Safety Commission

This document presents the policy proposed by the CNSC for the administration of requests for information and for public accessibility of information it holds. Comments are requested by May 2, 2003.
It is available through the CNSC website: < www.nuclearsafety.gc.ca >

For The People, Buy The People

by Jeremy Whitlock

It's mid-February, and the 100-foot-diameter hole in the ice of the Ottawa River looks very anomalous. Standing on a bluff below the NRU reactor, watching ducks splash playfully against the dark mass, one is given pause.

On the coldest days they're out there, when nose hairs snap like twigs and the hardiest of cross-country-ski commuters scurry for bus passes. The birds are, presumably, oblivious to the anthropogenic nature of the hole, as well as Nature's on-going struggle to close it.

It's enough to make the hypothermic mind reflect upon the constancies of the physical world, the necessities of life, and the delicate balance between the two.

In Ontario the electricity supply is a necessity of life suffering both neglect and abuse. At the outset of the last century Canada's most populous and industrialized province rightfully embraced electricity as a public asset, and explosive economic growth ensued.

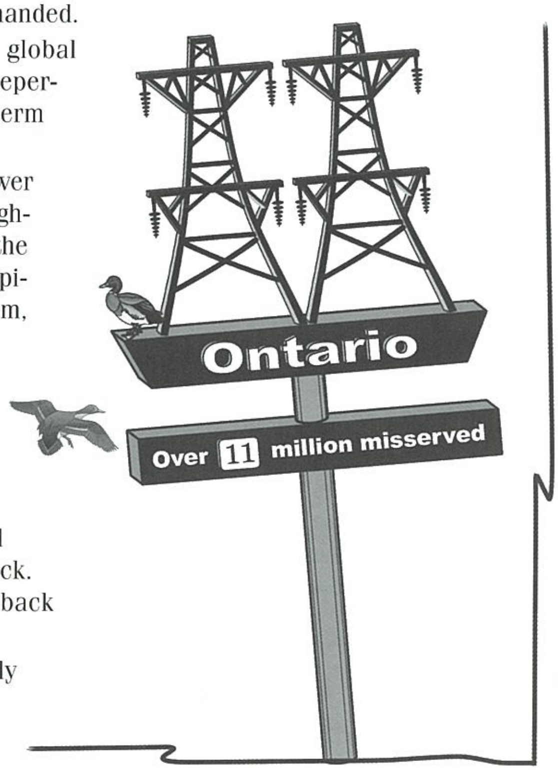
The motivation for public control over price and supply has changed little in the years since then:

- As a commodity lacking both a shelf life and a practical alternative, electricity's spot price is coupled rigidly to production, and the whims of machinery, labour, and climate.
- As both an economic and life-sustaining force, demand is guaranteed, and guarantees are demanded.
- As an evolving technology with global environmental and socio-political repercussions, investment must be long-term and development far-sighted.

In Ontario of late, the people's power has become the politician's puppet: a high-profile whipping boy for both sides of the Legislature, a laundromat for ulterior aspirations up and down the political spectrum, and a vehicle for tax camouflage.

Then, at the dawn of the new millennium: a poster-boy for privatization. As the provincial government conducted its scorched-earth policy for dealing with past mismanagement of the hydro portfolio, everything found itself quartered and on the auction block. Reality then dawned and the claw-back began. Investors backed off.

In January the Eves government finally killed the sale of Hydro One, after failing to find worthy suckers willing to underwrite 49% of a political tool.



Small wonder, following on the heels of the cancellation of free-market electricity retail in Ontario, now capped at 4.3 cents per kWh.

The government ended the experiment in light of an upcoming election, after a summer of shocking price volatility (partially caused, in turn, by an eroded electrical infrastructure from decades of political abuse.) They've rebated millions of bucks to the voters of Ontario and assert to be acting in the public interest, while filtering the cost of both the rebates and the on-going rate cap (for Ontario's electricity market continues) back to the consumers by less obvious means.

As disconcerting as this is, Ontarians can expect further meddling throughout the socio-economic infrastructure as Election Day draws near.

At the end of January eyebrows were raised in Ontario and elsewhere as hamburger mega-giant McDonald's announced its first-ever losing quarter. If ever there were a necessity of life, it's fast food, and fear of price escalation fuelled rumours of Premiere Eves contemplating intervention in the Ontario burger market.

Reportedly, stability would be imposed by a cap on the price of a Big Mac at $2.50, with a corresponding price freeze on Meal Deals that bundle the big burger with common peripherals.

As the Ontario burger market perseveres, the Eves government will be left to fund subsequent revenue shortfall directly from fee-for-use strategies, including the Playland, washrooms, and ketchup dispenser.

Likely to be decontrolled is the Special Sauce, with U.K. sauce giant HP Foods reportedly expressing an interest.

Lost socks found deep in the Playland will no longer be channeled to the Lost and Found, but sold on the biofuels market.

Perhaps it's the seemingly boundless capacity of elected officials to meddle that brings solace to the scene on the Ottawa River. Until ulterior agendas can craft ulterior physics, the ducks are safe.

The author claims a 49% non-controlling share of the responsibility for the veracity of this story.

CALENDAR

2003

Mar. 18, 19 — **CNA Nuclear Industry Seminar**
Ottawa, Ontario
Contact: Colin Hunt
CNA
Tel: 613-237-3010
e-mail: huntc@cna.ca

Apr. 2 - 4 — **International Exhibition on Nuclear Power Industry 2003**
Shenzhen, China
Contact: Costal International Exhibition Co. Ltd.
e-mail: general@coastal.com.hk
website: www.coastal.com.hk

Apr. 7 - 9 — **CANDU Reactor Safety Course**
Mississauga, Ontario
Contact: Dr. Dorin Nichita
AECL Mississauga
Tel: 905-823-9060 ext. 2221
e-mail: nichitae@aecl.ca

Apr. 7 - 11 — **MARC-6 Methods and Applications of Radioanalytical Chemistry**
Kona, Hawaii
website: www.wsu.ed/~rfilby/marc6

April 6 - 10 — **ANS Mathematics & Computation Topical Meeting**
Gatlinburg, Tennessee
Contact: Bernadette Kirk
ORNL
Tel: 865-574-6174
e-mail: kirkbl@ornl.gov

Apr. 20 - 23 — **ICONE II 11th International Congress on Nuclear Engineering**
Tokyo, Japan
Contact: Jovica Riznic
CSNC
Tel: 613-943-0132
e-mail: riznicj@cnsc-ccsn.gc.ca

May 4 - 7 — **ICAPP 03 International Congress on Advanced Nuclear Power Plants**
Cordoba, Spain
Contact: American Nuclear Society
website: www.ans.org/goto/icapp03

June 1 - 5 — **ANS Annual Meeting**
San Diego, California
e-mail: meetings@ans.org
web: www.ans.org

June 8 - 11 — **24th CNS Annual Conference and 28th CNS / CNA Student Conference**
Toronto, Ontario
Contact: CNS Office
Tel: 416-977-7620
e-mail: cns-snc@on.aibn.com

July 6 - 10 — **Plutonium Futures – the Science 2003**
Albuquerque, New Mexico
e-mail: puconf2003@lanl.gov
website: www.lanl.gov/pu2003

Sept. 15 - 19 — **International Conference on Advanced Nuclear Power Plants and Global Environment**
Kyoto, Japan
Contact: Atomic Energy Society of Japan
American Nuclear Society

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

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

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

Nov. 9 - 13 — **ANS/ENS International Winter Meeting**
New Orleans, LA, USA
Contact: American Nuclear Society
e-mail: meetings@ans.org
website: www.ans.org

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

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