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# de la Société Nucléaire Canadienne

May 2002 Mai

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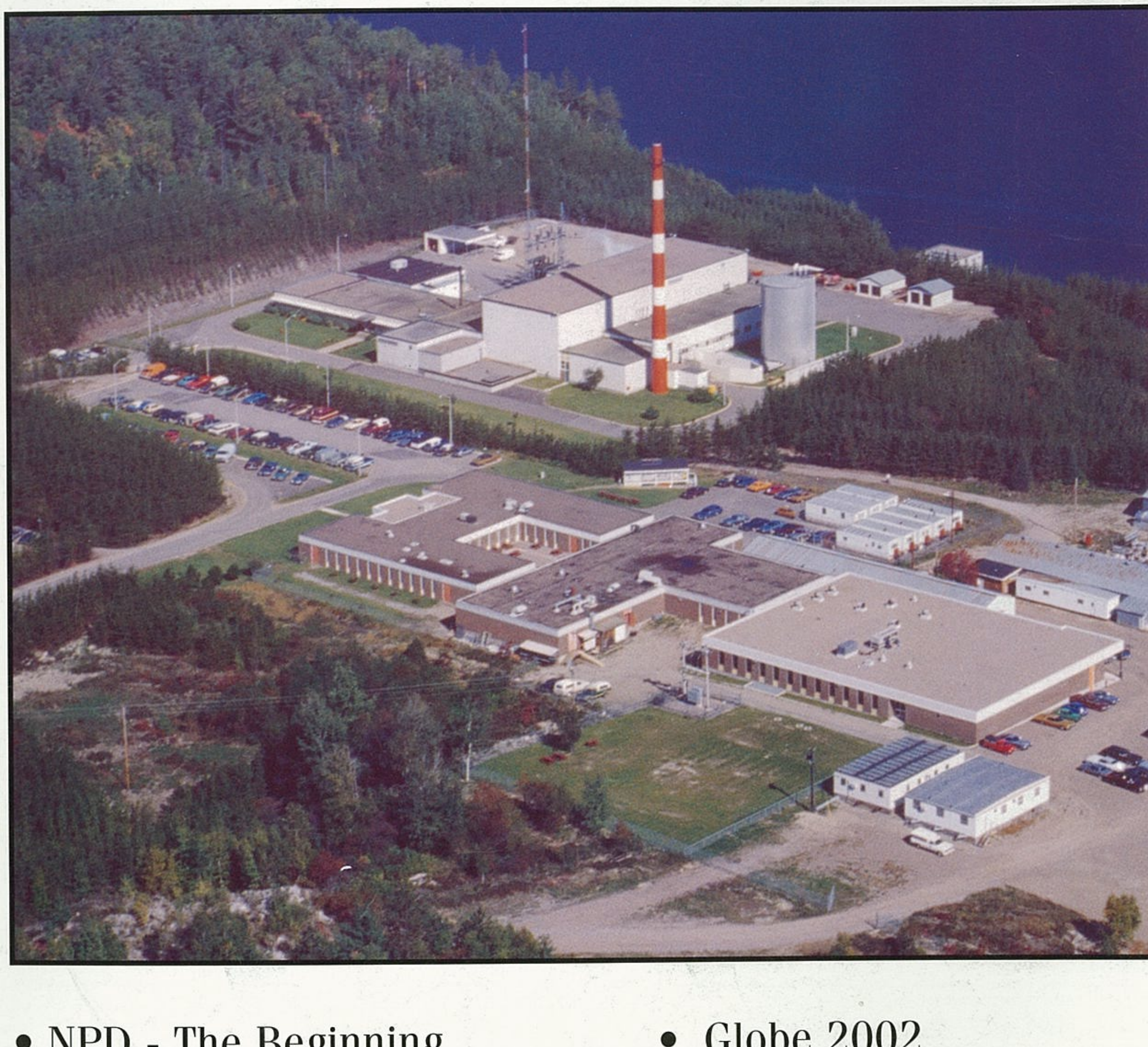

- NPD - The Beginning of CANDU
- Bringing Iter to Canada
- Nuclear Industry Winter Seminar
- Globe 2002
- Nuclear Education
- Fuel Manufacture in India

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*Cover Photo*

The photograph on the cover is an aerial view taken about 1970 of NPD with the buildings of the Nuclear Training Centre in the foreground.

*(Photo courtesy of Atomic Energy of Canada Limited)*

CANADIAN NUCLEAR SOCIETY

# bulletin

DE LA SOCIÉTÉ NUCLÉAIRE CANADIENNE

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# EDITORIAL

## Looking back, and forward

Two significant anniversaries this year turn our eyes to earlier events and achievements.

This is the 50th anniversary of the creation of Atomic Energy of Canada Limited. It was on April 1, 1952 that AECL officially came into existence. The federal government created the crown corporation to take over the facilities and work of the Chalk River Nuclear Laboratories that had been established and operated by the National Research Council and gave it a mandate to pursue commercial applications of the nuclear research and development of the previous decade.

It is also the 40th anniversary of the start-up of NPD, the small 20 MWe nuclear power demonstration that was our first nuclear power unit. The reactor of NPD first went critical in the early hours of April 11, 1962 and the plant began sending electricity to the Ontario Hydro grid on June 4 of the same year. Since NPD incorporated the essential features of CANDU; heavy water coolant and moderator, pressure tubes, oxide fuel in short bundles, on-power fuelling, computer control, it can be considered as the beginning of the successful CANDU line.

AECL's first decade was a heady one, with ambitious plans, challenging research and an air of excitement. Those were the days when problems were identified, researched and solved in weeks or months rather than years, typically by just a handful of dedicated but very capable people.

Today's environment is quite different. Although work is proceeding on advanced reactor designs and on new applications of radioisotopes, most of our current effort is going into maintaining and refurbishing the facilities we have. This is important but much less exciting than new research, new designs, new plants. One of the consequences has been that nuclear science and technology has become less attractive as a career choice and the number of young people pursuing studies in the field has dwindled. Given the ageing of our current nuclear workforce this is dangerous.

The industry has responded to some degree by funding chairs and providing scholarships, but much more needs to be done if the industry is to survive let alone revive and expand. In our view efforts are needed to reach students in high schools before they have chosen the direction they wish to pursue. One small step would be the donation of the recent book Unlocking the Atom to every high school library in the country.

*Fred Boyd*

# IN THIS ISSUE

First, our apologies for the lateness of this issue. Some communication problems combined with travel resulted in over two weeks lost time.

Part of this issue is drawn from two meetings: the annual Nuclear Industry Winter Seminar held in February and the Globe 2002 conference in March. Another focus is the upcoming 40th anniversary of the start-up of NPD, which, for many, marked the beginning of the CANDU series of nuclear power plants.

To start off, however, there is a letter from Archie Robertson commenting on the **MAPLE** reactors. Although his letter was written a few months ago the issue continues.

The first set of articles is titled **NPD - the beginning of CANDU** and begins with a background note prepared by Jeremy Whitlock in connection with the historic plaque to be erected near the NPD site, entitled **First nuclear-generated electricity in Canada (June 4, 1962).** This is followed by a retrospective piece, **NPD - a beginning,** a re-print of the press release of the day, **Reactor in Canada's First Nuclear Power station goes into Operation,** and some early photographs of a few of the people involved.

The next two articles deal with Iter, the proposed large thermonuclear fusion project. **Bringing Iter to Canada** is a slightly modified and updated version of the presentation by Peter Barnard to the Nuclear Industry Winter Seminar. It is followed by a technical description **The Iter Fusion Reactor** by Adam McLean.

Two other presentations from the Winter Seminar follow: **The Kyoto Protocol and Nuclear Power** and **Nuclear Energy and Sustainable Development.**

The broad theme of those two papers is continued in the report on **Globe 2002,** the large environmental conference held every four years in Vancouver. A side bar, **Nuclear Renaissance,** describes the first "nuclear" session in that series of conferences. Concluding the package is an extract from the presentation to that conference by David Anderson, federal Minister of the Environment, on **Canada and Climate Change.**

Then follows an eclectic selection of papers, the first, drawn from the CANDU Fuel Conference of last fall, on **Fabrication, Quality Assurance & Performance of PHWR Fuel in India.** Next is, **Control System Upgrades Support Better Plant Economics,** the second in a series. Finally, we present two articles on the broad issue of nuclear education. **Nuclear Education And Training In The Internet Age** was first presented at the 20001 CNS Annual Conference but, perhaps unfortunately, is still pertinent. **Nuclear Engineering Programmes at the Royal Military College** is the first of a two-part review.

Our modest section on **General News** again includes items that we found of interest and hope you do also.

There is, of course, the section on **CNS News,** a note on **Publications,** the updated Calendar and the ever interesting **Endpoint** by Jeremy Whitlock with another original drawing by his brother Lorne.

As always, we invite your reactions in the form of letters, e-mail, voice, or any other means of communication.

***Ed. Note:** The following letter from Archie Robertson, a former senior scientist at AECL-CRL, addressed to Linda Keen, president of the Canadian Nuclear Safety Commission, was copied to* CNS Bulletin *for publication. It was written at the end of January 2002.*

## Appalled about Maple

Dear Ms. Keen,

I am addressing this submission to the Commission through you as its Chair in my capacity as a private individual without affiliations.

I was appalled to learn that the MAPLE reactors at the Chalk River Laboratories are still not approved for active commissioning. I hold both the CNSC and AECL responsible for culpable delay in the licensing process for reasons that I will explain in what follows. The delay may cost MDS Nordion, the company that owns the reactors and will market the resulting radioisotopes, dollars but eventually it will be Canada, Canada's reputation, 34,000 patients depending on radioisotopes worldwide daily and health-service costs that will suffer.

The Commission is reported as saying that "the safety of the MAPLE reactors must come first." I would agree that no facility should be licensed if it is unsafe. However, there is no absolute safety, only relative safety or degree of safety. Requiring any one activity to be safer than others will result in resources being unavailable to improve the safety of less safe activities. This point was elaborated in "Basic Principles for Regulating Nuclear Activities", a report to the AEC Board by its Advisory Committee on Nuclear Safety, ACNS-24, 1996. I would hope that the CNSC in reaching its decisions is considering the consequences of further delay if this results in either shortages of radioisotopes or continuing operation of the NRU reactor which may be licensed to less rigorous criteria than those now required for the MAPLE reactors.

I attribute much of the delay to the failure of the CNSC (including its predecessor the AECB) to publish regulatory documentation appropriate to reactors that do not produce electric power: and to AECL's proceeding with design and construction of the reactors in the absence of such documentation. In that indefensible situation AECL should have proposed licensing criteria to the AECB/CNSC to seek agreement before committing significant resources.

The AECB/CNSC has been repeatedly advised of the need for improved documentation. In 1990 a committee advising the Minister to whom AECB reported stated that it had "identified several areas of greatest concern deserving priority attention" including Documentation of AECB policies and requirement in many areas, through the consultative process" (see AECB report INFO-0725). Following this review, increased resources were assigned to the AECB to correct deficiencies. Also in 1990 the ACNS, in report ACNS-14, identified the need for publication of "the objectives, principles and requirements for the safety of mini-reactors". (The term "mini-reactor" specifically included MAPLE reactors.) The Auditor General's Report for 1994, Vol. 10, Chapter, recommended that: "The Atomic Energy Control Board should document more fully its regulatory requirements, including the important precedents or regulatory positions that form the basis or rationale for them". The AECB Response stated "Agreed". In 2001 the ACNS submitted to the CNS Commission its report INFO-0725 in which it reviewed the CNSC's Regulatory Documentation. This report made 27 recommendations for improvements. It might be argued that the Nuclear Safety and Control Act and its dependent Regulations provide the needed documentation. However, this would not explain the many regulatory documents relating to power reactors, for which no equivalent documents exist for mini-reactors. At an open meeting in 2001 an AECL staff member stated that MAPLE is now being built to satisfy most of the power reactor requirements. I consider that some exceptions may be significant but if this involves unnecessary costs to achieve excessive safety, as argued above, the CNSC and AECL jointly would be responsible for wasting resources that could be better expended elsewhere. Had the AECB/CNSC issued the required documents in draft form for consultation in accordance with its normal praiseworthy practice, it would have been possible for interested parties to challenge their provisions.

I am not challenging any of the decisions of the Commission or its staff. Rather, the purpose of this submission is to draw to the attention of the Commission the consequences of its failure to provide adequate documentation, with specified regard to the licensing of non-power reactors.

As already indicated, AECL must share the blame for any waste of resources resulting from delays in licensing these reactors. In 1991 I chaired an external peer review of the MAPLE-X design, commissioned by AECL. While it would be improper for me to reveal the details of that review, its findings have contributed to my present position: some construction was already in progress then. The AECL Annual Report for 1991-92 referred to "the MAPLE-X10 reactor now being constructed for radioisotope production". However, it seems that the AECB did not issue its Nuclear Reactor Construction Approval until 1997 (AECB Annual Report 1997-98). Furthermore, media reports indicate that some of the delays have been due to the AECB/CNSC's repeated dissatisfaction with AECL's quality management. This is particularly disappointing in view of the fact that AECL has operated a quality assurance program, by one name or another, for two decades.

The delays and their consequences are thus partly attributable to institutional failings, i.e., where the cause extends beyond the immediate agent as explained in report ACNS-17, within both AECB/CNSC and AECL. That report, submitted to the Board in 1990, stressed the need for quality assurance programs applicable to institutions, including the regulatory body, to prevent institutional failings.

A 1995 report by the ACNS to the Board (ACNS-22) emphasized the importance of feedback of operating experience, stating: "The feedback process is not completed until the lessons learned from past experience are applied to revise, as appropriate, existing policies and procedures of the operating organization". From the history of the MAPLE reactors it appears that neither the CNSC nor AECL has learned its lessons.

*J.A.L. Robertson*

# NPD—The Beginning of CANDU

***Prologue:***

*It was called NPD, an acronym for Nuclear Power Demonstration, and it produced only 20 megawatts of electricity, but it was the first of the successful CANDU series of nuclear power plants.*

*The reactor of NPD first went critical in the early hours of April 11, 1962 and the plant began sending electricity to the Ontario Hydro grid on June 4 of the same year, 40 years ago.*

*That 40th anniversary and the significance of NPD will be commemorated in two ways this year. The annual conference of the Canadian Nuclear Society, to be held in June 2002, has as its theme* "40 Years of Nuclear Power in Canada, Celebrating the Past, Looking to the Future". *And, thanks to the initiative and hard work of Jeremy Whitlock, an historic plaque will be erected on Ontario's Highway 17 near the site of the former station, about 20 kilometres west of AECL's Chalk River Laboratories. That ceremony will take place June 1, 2002.*

*As our part of the recognition of the 40th anniversary of the start-up of NPD, we present:*

- *the background note prepared by Jeremy Whitlock in support of the application for an historic plaque*
- *a reprint of a reminiscent article by the editor first printed in Vol. 13, No. 2 issue of the CNS Bulletin (just 10 years ago)*
- *the press release issued on the day NPD started up (April 11, 1962), and*
- *some ancient photographs.*

*We hope you enjoy this foray into the past.*

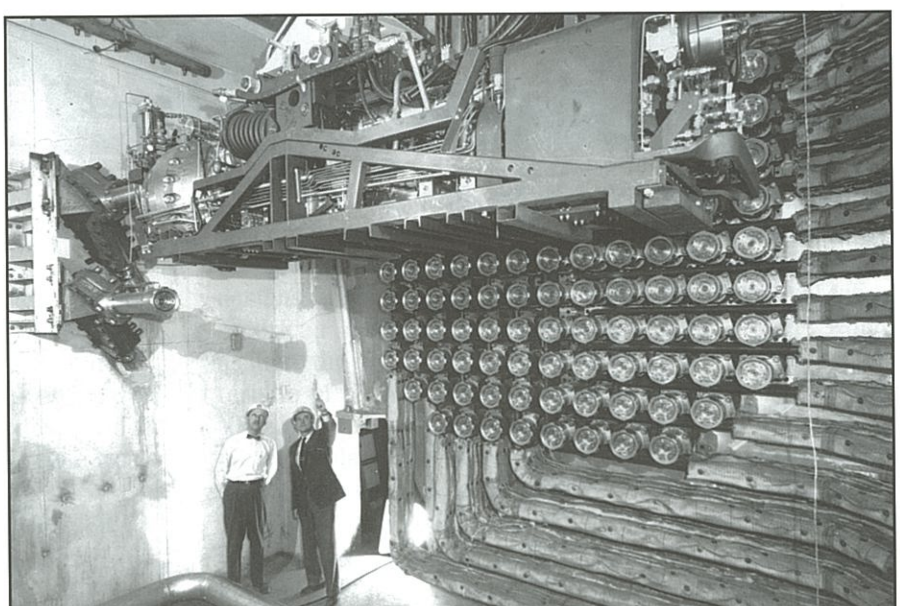
## First Nuclear-Generated Electricity in Canada (June 4, 1962)

*Background Information prepared by Jeremy Whitlock*

***Ed. Note:*** *The following "essay" was prepared by Jeremy Whitlock in support of the application by the Canadian Nuclear Society for the erection of an historic plaque near the NPD site.*

The story of this historic achievement of 1962 begins shortly before the outbreak of World War II, with the German discovery of nuclear fission. Scientists everywhere immediately realized the potential of this new energy source, and in Canada Dr. George Laurence conducted some of the world's first "critical pile" fission experiments at the National Research Council (NRC) laboratories in Ottawa.

Meanwhile, a handful of French scientists escaped to Britain from Paris with almost all the world's supply of heavy water (about 200 kg), just ahead of the German invasion. They and the heavy water eventually ended up in Montreal. While the remainder of Canada's wartime nuclear effort was devoted to helping the American bomb program, the end of hostilities in 1945 found this country with the second largest nuclear research infrastructure in the world (after the U.S.).



*A view of one end of the NPD reactor and a fuelling machine, taken shortly before start-up on April 11, 1962. The fuelling machine is turned to connect with the discharge port.*

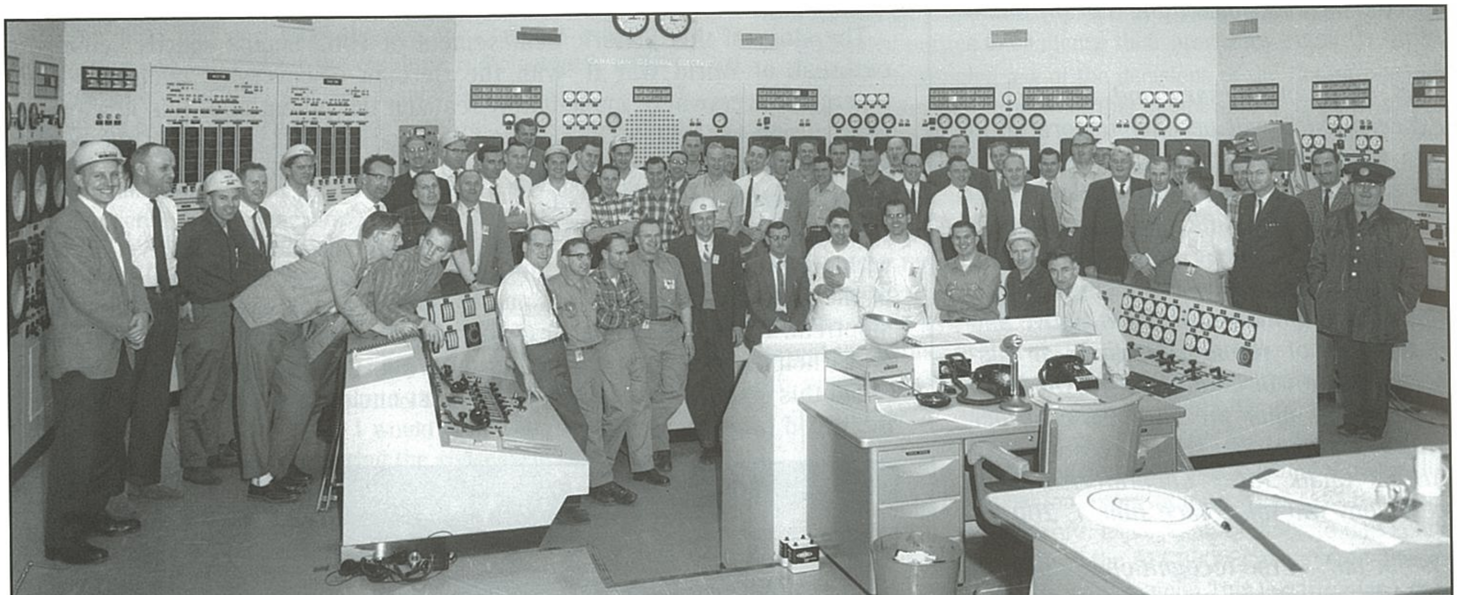
Part of this legacy was the ZEEP nuclear research reactor at the Chalk River Laboratories (about 200 km northwest of Ottawa), the only non-U.S. reactor at the time, commemorated in 1966 by a plaque from the Archaeological and Historic Sites Board of Ontario.

With the wartime diversion out of the way, scientists again turned to the alluring peaceful potential of nuclear energy. In 1950 George Laurence, now at Chalk River Laboratories, began advocating a Canadian power reactor based upon natural uranium fuel and heavy water—both areas of domestic expertise. As the only member of the wartime British-Canadian-American nuclear alliance not to pursue atomic weaponry after the war, Canada found itself cut off from technological cooperation with the other two, and forced to go it alone.

August of 1951 saw the formal publication of "An Atomic Power Proposal", by Dr. W. Lewis of Chalk River Laboratories. The following January a series of meetings between Ontario Premier Leslie Frost, Ontario Hydro (then the Hydro-Electric Commission) Chief Engineer Richard Hearn, National Research Council (NRC) President C.J. Mackenzie, and federal minister C.D. Howe, lead to preliminary joint feasibility studies between Ontario Hydro and the newly-created crown corporation Atomic Energy of Canada Ltd. (AECL had taken over the reins of Canada's nuclear research program from the NRC in April 1952).

In 1954 the "Nuclear Power Group" was established at Chalk River Laboratories (now part of AECL), under the leadership of Ontario Hydro's Harold Smith. This handful of representatives from electric utilities, engineering companies, and manufacturers, joined with AECL's scientists to forge the fundamental design of a prototype heavy-water, natural-uranium-fuelled power reactor that could compete with coal-fired plants.

Although"made-in-Canada" was the overlying goal of this enterprise, "made-in-Ontario" largely resulted by default. Ontario not only provided the industrial base for much of the manufacturing, but was also the seat of Canada's nuclear



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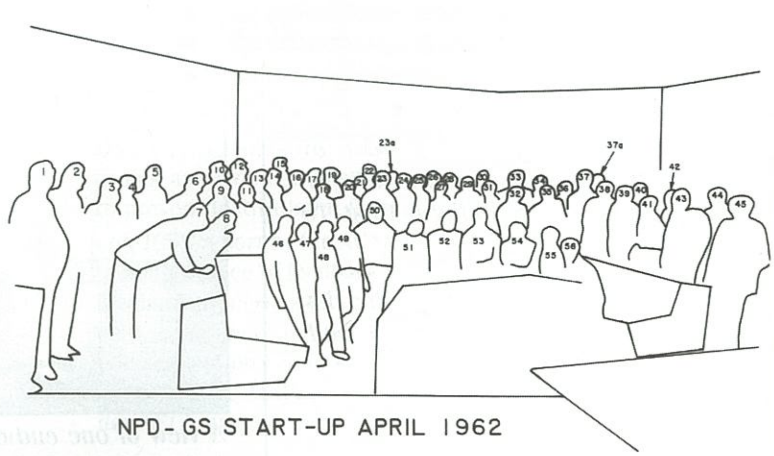
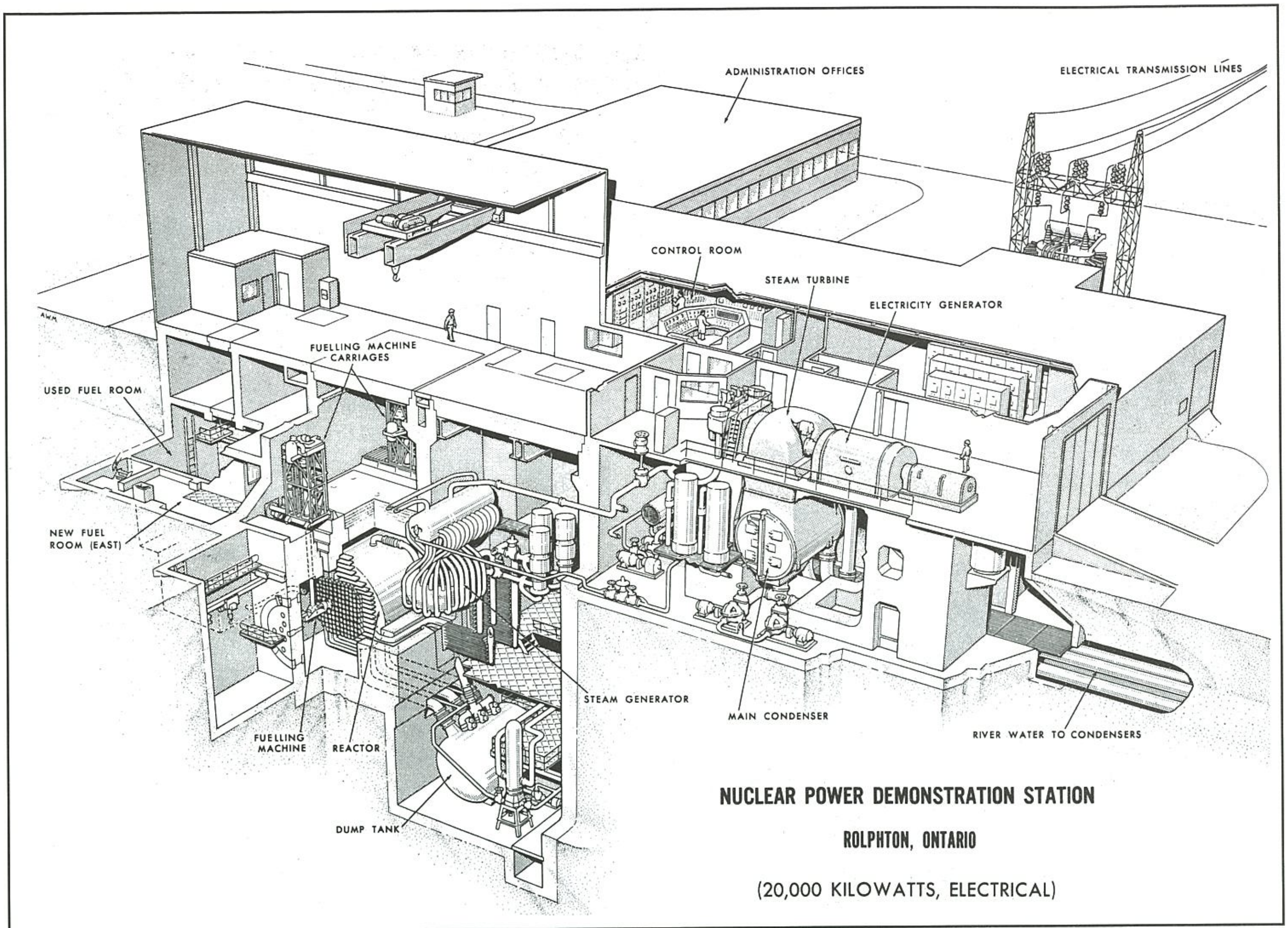
| 1. | J. JENNEKENS | AECB | 29. | D. KNICKLE | CGE |
| 2. | P. GRAY | USAEC | 30. | D. MORGAN | CGE |
| 3. | J. FREE | PNGS | 31. | J. GRAHAM | CGE |
| 4. | S. McEWEN | PNGS | 32. | S. HORTON | Supply Div. |
| 5. | J. McBRIDE | BNGS | 33. | J. KINGSTON | CGE |
| 6. | J. BEAVER | AECL | 34. | J. HILBORN | AECL |
| 7. | F. BOYD | AECB | 35. | D. MILLEY | NPD |
| 8. | N. KLINGBIEL | CGE | 36. | G. WILLIAMS | BNPDS |
| 9. | G. HOWEY | NTC | 37. | K. KEANE | PNGS |
| 10. | G. GIBSON | CGE | 37a | A. WARD | AECL |
| 11. | F. BOLTON | CGE | 38. | D. KEYES | AECL |
| 12. | C. WHITTIER | CGE | 39. | G. JAMES | AECL |
| 13. | C.E. TILL | ANL Argonne | 40. | D. BRECKON | AECL |
| 14. | J. WOOD | CGE | 41. | L. McCONNELL | Prod. & Tr. |
| 15. | C. KENNEDY | AECL | 42. | A. BELBIN | PNGS |
| 16. | L. JOLLEY | BNGS | 43. | L. HAYWOOD | AECL |
| 17. | D. McKEE | BNGS | 44. | S. DUBEK | AECL |
| 18. | O. ALLESIO | NTC | 45. | G. WALKER | NPD |
| 19. | G. HORRICKS | NPD | 46. | J. HAMMOND | NGD |
| 20. | F. MAYBURY | BNGS | 47. | K. ELSTON | BNGS-B |
| 21. | D. NICHOLS | AECL | 48. | L. WOODHEAD | NGD |
| 22. | R. URQUHART | Design | 49. | E. HORTON | BNPD |
| 23. | V. McCALL | NTC | 50. | W. BROWN | CGE |
| 23a | D. LEACH | DP | 51. | W. WILLIAMS | CNS |
| 24. | G. VIVIAN | D&D | 52. | R. IVINGS | DP |
| 25. | R. CANDLISH | BNGS Con. | 53. | T. NICKS | NPD |
| 26. | T.O. BAILEY | DP | 54. | E. SAWCHUK | NPD |
| 27. | B. CARTWRIGHT | BNGS Con. | 55. | V. AUSTMAN | BNGS |
| 28. | V. BONCH | CGE | 56. | R. SHAVE | DP |
| | | | Photo – C. BASKIN | | AECL |




*This photograph was taken in the early hours of April 11, 1962 in the control room of NPD shortly after the successful start-up of the reactor at 2:40 a.m.*




*Nuclear Power Demonstration Station, Rolphton, Ontario (20,000 kilowats, electrical)*

engineering and scientific expertise, as well as uranium production (mined at Elliot Lake, north of the Lake Superior).

In March of 1955, Canada General Electric (CGE, now GE Canada) in Peterborough, Ont. was selected from seven bids as the Prime Contractor for the Nuclear Power Demonstration (NPD) project. The implementation team was now in place: CGE would provide the design work at its Peterborough engineering offices (forming the Civilian Atomic Power Division, CAPD), as well as $2 million in funding. Ontario Hydro would provide the plant site and all conventional equipment, plus operate the plant and purchase the nuclear-generated steam. AECL would provide the balance of funding (the projected cost at that time was $20 million) and own the nuclear side of the plant.

The site itself was a spot on the Ottawa River, just downstream from Ontario Hydro's massive Des Joachims hydroelectric power station at Rolphton, Ont. (about 230 km north-west of Ottawa).

The CAPD in Peterborough included roughly a dozen engineers each from CGE and AECL, under the guidance of General Manager Ian McRae (CGE), Engineering Manager Ian Mackay (AECL), and Design Manager John Foster (AECL). These were heady days, where design and development proceeded in parallel, and key late-breaking design decisions became the blueprint for future CANDU designs.

The most significant of these decisions was made in 1957, when the team resolved to redesign the core of the reactor to better reflect the thinking on future CANDU designs. Instead of having one large pressure vessel, as in American designs then being developed, NPDF would assume the horizontal, pressure-tube arrangement characteristic of all CANDU cores to this day. This would make NPD the first commercial power reactor to have a completely replaceable core, and able to refuel while operating at full power—both signature CANDU traits.

This decision also ensured that the manufacturing phase would approach 100% Canadian content, since the specifications now more closely matched our industrial capabilities at the time. More important, it meant that international experience would be largely irrelevant to the Canadian nuclear program: our bold decision to be unique also meant self-reliance.

As the hurdles and delays were gradually overcome, an Operations group, assembled under Lorne McConnell of Ontario Hydro, prepared to take over and bring Canada into the Nuclear Power Age.

NPD began supplying its first electricity to the Ontario grid on June 4, 1962, and reached full power (about 20 MWe—enough for 10,000 homes) on June 28. Ontario Hydro would continue to operate the plant for the next 25 years, even as much larger CANDU versions came on-stream in Southern Ontario, dwarfing NPD's meagre contribution. Today Ontario is one of the largest nuclear-powered jurisdictions in the world.

The more important role of NPD was always as a prototype for CANDU engineering. Over the years it was an invaluable test bed for new fuels, materials, components, and instruments—most never envisaged at the time of NPD's conception.

Equally important, NPD was the training centre for generations of Canadian and off-shore operations staff. This role began shortly after the start of operation, when a training program was set up by George Howey of Ontario Hydro. Howey was to oversee the evolution of the training and simulation centre over the next two decades.

In 1987 a decision was made to shut down NPD permanently, based upon unsupportable maintenance costs. In its 25-year career it had met and surpassed every goal set for it, and was a strong symbol of Canadian innovation, boldness, tenacity, and self-reliance.

NPD also epitomized the symbiotic good that can come of federal/provincial/private cooperation in research and development. The partnership forged in the early 1950s between AECL and Ontario Hydro (now Ontario Power Generation) continued and prospered—and served as a model for other utilities in Quebec and New Brunswick that later installed CANDU reactors. The participation of private manufacturing and engineering firms (headed by CGE) has evolved into a well-established nuclear industry to which most CANDU construction and design contracts are now channeled.

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# NPD—A Beginning

*by Fred Boyd*

***Ed. Note:** The following note is reprinted from the Vol. 13, No. 2, summer 1992, issue of the* CNS Bulletin *and is drawn from the editor's personal involvement with NPD.*

Like the birth of the first child; it was in the middle of the night, thirty years ago last month, that NPD, Canada's first nuclear power plant, went critical.

At 2:40 a.m., the morning of April 11, 1962, with about thirty intensively interested onlookers, the neutron counters took off, indicating that the self-sustaining chain reaction had begun.

For hours, from the previous afternoon, the moderator level had been inched up ("inches" were used in those days) and points on the inverse count-rate plotted. So everyone at the station expected the birth and was on hand to celebrate.

Less than two months later, on June 4, the first electricity generated by nuclear fission in Canada was delivered from NPD to Ontario Hydro's transmissions lines.

NPD was a small plant—rated at only 20MWe—but it pioneered most of the distinctive features of CANDU reactors—pressure tubes surrounded by calandria tubes in a horizontal configuration; pressurized heavy water coolant; heavy water moderator; natural uranium fuel using UO2 in short bundles of pencils; automatic control.

Only a few years earlier it had begun as a different design. When the Nuclear Power Group, convened at Chalk River in the early 1950's, concluded that a natural uranium fuelled, heavy water moderated reactor was a practical approach for a power reactor, planning began for a demonstration plant.

Eventually, Canadian General Electric was chosen to design and build the plant, with Ontario Hydro to own the conventional part and operate it. AECL would own the nuclear portion. (That story is well recorded in several books.)

In the early summer of 1955 Ian MacKay left Chalk River to head up the CGE design team, with John Foster (on loan from Montreal Engineering) as his deputy. Others from CRNL joined, a few transferred from within CGE and a few (such as the author) were recruited from elsewhere.

# Some of The People Involved

***Ed. Note:*** *The following photographs are reproduced from a publication issued in June 1962 shortly after NPD had been connected to the grid.*

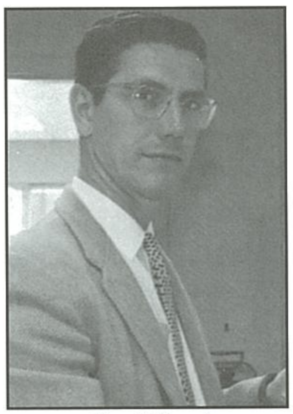
*Lorne McConnell*

*Sam Horton*

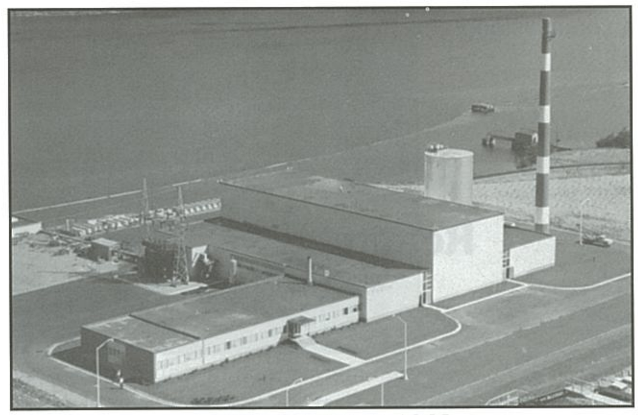
*Elgin Horton*

*Roger McKenzie*

*Ed Sawchuk*



*Fred Boyd*



*A view of NPD in 1962.*

By September the group had grown to about 25. Even at the peak of work the design team never exceeded about 50! It was a young group—the eldest was still in his thirties. Everyone was housed in one large room at CGE's Peterborough works, with cubicles for one, two or four (depending on status). At the beginning even the partitions did not exist.

The initial design was for a vertical pressure vessel concept. While this design proceeded the NPG and others at Chalk River were keeping an eye on developments of zirconium alloys. The pressure tube concept had been considered in the conceptual phase and preferred since the physical limitations of pressure vessels were recognized. The only available material at the time with sufficiently low neutron corss section for a natural uranium arrangement was aluminum whose temperature characteristics precluded its use in a power reactor. By 1957 sufficiently positive information about zirconium became available that work on the pressure vessel design was stopped. For a few months the designers at CGE waited in frustration.

Then came the word. Redesign the reactor in the pressure tube concept—but save as much of the earlier design as possible since construction had already begun. So, NPD-2 began. An early decision was to use the excavation that was completed and partially concreted. The partially built pressure vessel (about 12 foot diameter) in Scotland was written off. (No one seems to know where it went.)

Rapidly the now well-known pressure tube design evolved. A major challenge—designing an on-power fuel changing system—was taken on by Bill Brown and his group. The NPD fuelling machines worked remarkable well for the 25 year life of the station and their design served as a basis for subsequent CANDU machines.

Every aspect of the design had to be vetted by Dr. W.B. Lewis and his associates at AECL. Almost every month two car loads of CGE staff would travel to Chalk River for a design review meeting. Given that many of these trips were in the winter and over back roads from Peterborough to Pembroke the general consensus of the design group was that the most hazardous aspect of nuclear power was the

As the hurdles and delays were gradually overcome, an Operations group, assembled under Lorne McConnell of Ontario Hydro, prepared to take over and bring Canada into the Nuclear Power Age.

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The more important role of NPD was always as a prototype for CANDU engineering. Over the years it was an invaluable test bed for new fuels, materials, components, and instruments—most never envisaged at the time of NPD's conception.

Equally important, NPD was the training centre for generations of Canadian and off-shore operations staff. This role began shortly after the start of operation, when a training program was set up by George Howey of Ontario Hydro. Howey was to oversee the evolution of the training and simulation centre over the next two decades.

In 1987 a decision was made to shut down NPD permanently, based upon unsupportable maintenance costs. In its 25-year career it had met and surpassed every goal set for it, and was a strong symbol of Canadian innovation, boldness, tenacity, and self-reliance.

NPD also epitomized the symbiotic good that can come of federal/provincial/private cooperation in research and development. The partnership forged in the early 1950s between AECL and Ontario Hydro (now Ontario Power Generation) continued and prospered—and served as a model for other utilities in Quebec and New Brunswick that later installed CANDU reactors. The participation of private manufacturing and engineering firms (headed by CGE) has evolved into a well-established nuclear industry to which most CANDU construction and design contracts are now channeled.

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# NPD—A Beginning

*by Fred Boyd*

***Ed. Note:*** *The following note is reprinted from the Vol. 13, No. 2, summer 1992, issue of the* CNS Bulletin *and is drawn from the editor's personal involvement with NPD.*

Like the birth of the first child; it was in the middle of the night, thirty years ago last month, that NPD, Canada's first nuclear power plant, went critical.

At 2:40 a.m., the morning of April 11, 1962, with about thirty intensively interested onlookers, the neutron counters took off, indicating that the self-sustaining chain reaction had begun.

For hours, from the previous afternoon, the moderator level had been inched up ("inches" were used in those days) and points on the inverse count-rate plotted. So everyone at the station expected the birth and was on hand to celebrate.

Less than two months later, on June 4, the first electricity generated by nuclear fission in Canada was delivered from NPD to Ontario Hydro's transmissions lines.

NPD was a small plant—rated at only 20MWe—but it pioneered most of the distinctive features of CANDU reactors—pressure tubes surrounded by calandria tubes in a horizontal configuration; pressurized heavy water coolant; heavy water moderator; natural uranium fuel using UO2 in short bundles of pencils; automatic control.

Only a few years earlier it had begun as a different design. When the Nuclear Power Group, convened at Chalk River in the early 1950's, concluded that a natural uranium fuelled, heavy water moderated reactor was a practical approach for a power reactor, planning began for a demonstration plant.

Eventually, Canadian General Electric was chosen to design and build the plant, with Ontario Hydro to own the conventional part and operate it. AECL would own the nuclear portion. (That story is well recorded in several books.)

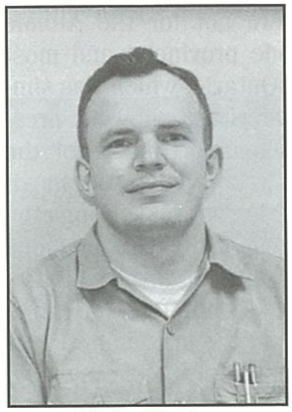
In the early summer of 1955 Ian MacKay left Chalk River to head up the CGE design team, with John Foster (on loan from Montreal Engineering) as his deputy. Others from CRNL joined, a few transferred from within CGE and a few (such as the author) were recruited from elsewhere.

## Some of The People Involved

***Ed. Note:*** *The following photographs are reproduced from a publication issued in June 1962 shortly after NPD had been connected to the grid.*

*Lorne McConnell*

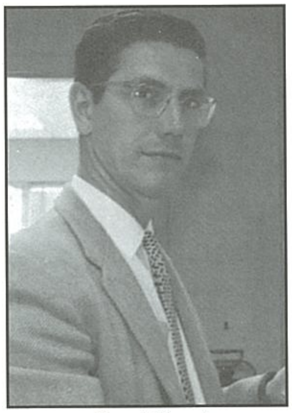
*Sam Horton*



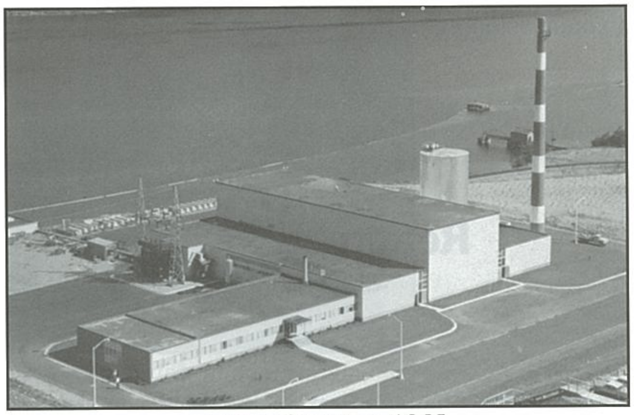
*Elgin Horton*

*Roger McKenzie*

*Ed Sawchuk*



*Fred Boyd*



*A view of NPD in 1962.*

By September the group had grown to about 25. Even at the peak of work the design team never exceeded about 50! It was a young group—the eldest was still in his thirties. Everyone was housed in one large room at CGE's Peterborough works, with cubicles for one, two or four (depending on status). At the beginning even the partitions did not exist.

The initial design was for a vertical pressure vessel concept. While this design proceeded the NPG and others at Chalk River were keeping an eye on developments of zirconium alloys. The pressure tube concept had been considered in the conceptual phase and preferred since the physical limitations of pressure vessels were recognized. The only available material at the time with sufficiently low neutron corss section for a natural uranium arrangement was aluminum whose temperature characteristics precluded its use in a power reactor. By 1957 sufficiently positive information about zirconium became available that work on the pressure vessel design was stopped. For a few months the designers at CGE waited in frustration.

Then came the word. Redesign the reactor in the pressure tube concept—but save as much of the earlier design as possible since construction had already begun. So, NPD-2 began. An early decision was to use the excavation that was completed and partially concreted. The partially built pressure vessel (about 12 foot diameter) in Scotland was written off. (No one seems to know where it went.)

Rapidly the now well-known pressure tube design evolved. A major challenge—designing an on-power fuel changing system—was taken on by Bill Brown and his group. The NPD fuelling machines worked remarkable well for the 25 year life of the station and their design served as a basis for subsequent CANDU machines.

Every aspect of the design had to be vetted by Dr. W.B. Lewis and his associates at AECL. Almost every month two car loads of CGE staff would travel to Chalk River for a design review meeting. Given that many of these trips were in the winter and over back roads from Peterborough to Pembroke the general consensus of the design group was that the most hazardous aspect of nuclear power was the design review meetings.

As well as designing a new machine, a number of fundamental concepts had to be tackled. As an example, the question of pressure relief valves on the primary heat transport system threatened an impasse. A policy had been adopted earlier to try to work within existing regulations that would be applicable if it were not for the Atomic Energy Control Act (which overrode provincial and most other legislation). The boiler act of Ontario, which was similar to others throughout North America, called for pressure relief valves sized for the maximum power of the energy source. The question then was, what is the maximum possible power of the reactor? Eventually, through the wisdom of Grant Gibson, whose responsibilities included the Boiler and Pressure Vessel Act, and the involvement of the AECB's Reactor Safety Advisory Committee (of which he was a member) it was agreed that the maximum power would be that allowed by the reactor protective system. Consequently, the relief valves were sized just for the case of uncontrolled operation of the heaters on the pressurizer.

Many of the designers were involved in the installation and commissioning of the equipment or systems they had designed. This provided very effective and rapid "feedback" which, unfortunately, was partially lost when the design of the next station—Douglas Point—was assigned to the newly created Power Projects group in Toronto.

On the operations side Ontario Hydro hired Lorne McConnell as NPD's first superintendent. After spending a couple of years with the designers providing invaluable operations perspective, he moved to NPD with his small band of supervisors. His policy, endorsed by Ontario Hydro, was to engage the best people he could find and then subject them to intense training. That he succeeded is evident in the names of some of that original group, such as: Sam and Elgin Horton, Larry Woodhead, Verne Austman, Roger McKenzie, Ken Elston and others.

NPD was shut down in 1987 after 25 years operation (although it was originally intended for only 10). During that time ti provided much useful information, served as a test bed for several new ideas, and was a training centre for many of Ontario Hydro's nuclear operations staff.

NPD's legacy lives on in the many CANDU plants in Canada and abroad.

***Press release of April 11, 1962***

# Reactor in Canada's First Nuclear Power Station Goes into Operation

The reactor in Canada's first nuclear power station went into operation today, it was announced by the Hon. Gordon Churchill, chairman, committee of the Privy Council on Scientific and Industrial Research. Commissioning of the station is continuing and the first electricity will be produced within the next few months.

Known as the Nuclear Power Demonstration (NPD), the plant is near Rolphton, Ont., about 150 miles west northwest of Ottawa and 12 miles up the Ottawa River from the Chalk River research centre of Atomic Energy of Canada Limited.

After extensive testing of the complex electronic circuits and various plant systems, heavy water was pumped into the aluminum reactor tank that contains the uranium oxide fuel. At 2:40 a.m. today a neutron counting instrument in the station control room indicated that a chain reaction had been achieved.

This means that the "furnace" or reactor in the power station was "burning" uranium for the first time. Various commissioning tests will be carried out during the next few months before the reactor is brought up to its full heat output and steam is fed from the steam generator into the turbine-generator unit to produce electricity.

The $33 million NPD station was built as a co-operative project of Atomic Energy of Canada Limited, Ontario Hydro and Canadian General Electric Company Limited. The plant, which will have an electrical output of 20,000 kilowatts, is a prototype for large plants, such as the 200,000 kilowatt Douglas Point Nuclear Power Station now under construction on the eastern shore of Lake Huron, midway between Port Elgin and Kincardine, Ont.

CGE, under contract to AECL and Ontario Hydro, was responsible for the design, development and construction of the station. AECL provided research and development data for and owns the nuclear portion of the plant. Ontario Hydro designed and owns the conventional portion of the plant. Ontario Hydro operates the station and will pay AECL for the steam fed to the turbine.

The reactor is an aluminum tank 15 feel long and 17 feet in diameter. Through this tank run 132 horizontal aluminum tubes into which are inserted zirconium alloy pressure tubes that contain the uranium oxide fuel.

The fuel consists of bundles of zirconium alloy tubes, 19 1/2 inches long, that contain small pellets of uranium dioxide. The outside diameter of each fuel bundle is 3.23 inches. There are 11888 fuel bundles, each containing about 33 pounds of uranium dioxide, making a total of about 20 tons of fuel.

When operating at its full heat output, the reactor will contain about 60 tons of heavy water moderator. The heavy water surrounds the fuel and slows down neutrons (moderates their speed) sufficiently to enable a chain reaction to take place. The chain reaction is a successive splitting of uranium atoms, often termed the "burning" of the uranium, that releases large quantities of heat.

Heavy water is pumped into the pressure tubes containing the hot fuel bundles. This heavy water, called the "coolant" because it takes away the heat generated in the fuel, is then pumped to a steam generator where the heat is transferred to ordinary water. The latter is sufficiently heated to convert it to steam, which drives the turbine. The turbine drives the electricity generator.

*A partial view of the parade of vehicles carrying the calandria and endshields for the NPD reactor as it passed through Deep River in the summer of 1961.*

*NPD as it is today.*

# Bringing Iter to Canada: An Update

***Ed. Note:*** *Following is a slightly modified and updated version of the presentation by Dr. Peter Barnard, Chairman and CEO of Iter Canada, to the Nuclear Industry Winter Seminar in Ottawa, February 18, 2002, by Laura Ferguson of Iter Canada*

Back in 1985, Ronald Reagan, Mikhail Gorbachov and other world leaders launched one of the most ambitious projects in history - the Iter fusion energy research and development project. Often described as the "Olympics of Science", the Iter project builds on decades of fusion research worldwide, involving more than 30 countries. The word "Iter" is Latin for "the way", a reference to the path taken by the international science community toward development of a new cleaner energy source for the future.

Iter would be the world's largest international cooperative research and development project next to the Space Station, and would be constructed for approximately $6 billion over 8 years and operated for about the same amount over 20 years.

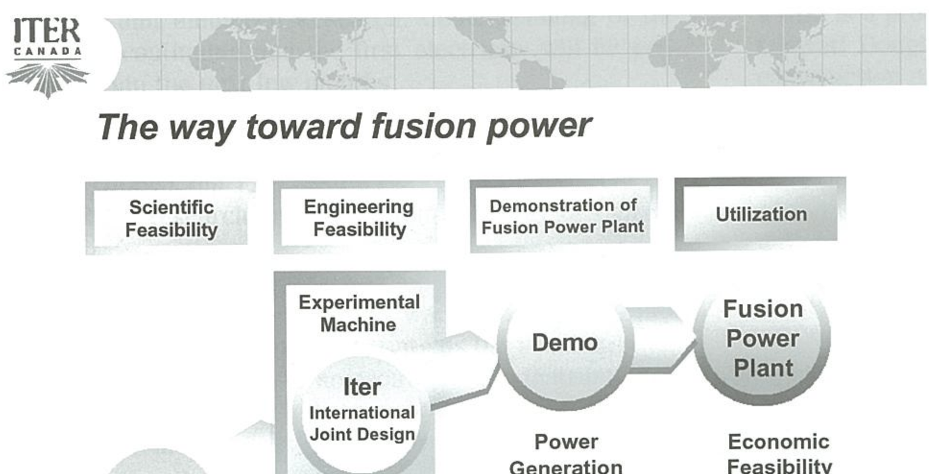
Current fusion research is being conducted at four large Tokamaks-one in Princeton in the United States, one in Naka, Japan, one in Moscow, and the Jet facility just outside of Oxford in England. The basic technology of the Iter facility is the Tokamak (pictured on the cover), which was a Russian invention. The Iter Tokamak will be about three times larger than the one in operation at the Jet facility in England. *(See a technical description by Adam McLean in this issue of the* CNS Bulletin.*)*

Iter is the next stage is fusion research and is meant to demonstrate the technological and scientific feasibility of fusion power. It is to be the final stage before an actual demonstration power plant is built and fusion energy becomes a commercial reality. (See Fig.1) (visual "The way towards fusion power")

Canada, the European Union and Japan have all expressed an interest in hosting Iter. On June 7, 2001 Canada's Ambassador to Russia, Rod Irwin, launched Canada's bid at a meeting of the international Iter participants in Moscow. Canada's site is in the town of Clarington, east of the Greater Toronto Area on the north shore of Lake Ontario. It is located between the Darlington Nuclear Generating Station (where Darlington 2 would have been built) and the St. Mary's Cement plant. (See Fig.2)

This site has many advantages. Among them is its proximity to the Greater Toronto area. This makes it an attractive living location for the 250 international scientists who would come with their families to work at Iter.

Another great advantage is that Iter will require tritium as one of its fuels for the fusion reaction, and the only adequate supply in the world for the Iter project is currently stored at the Tritium Removal Facility at the Darlington plant next door. Locating Iter anywhere else but Clarington would require shipping tritium over public roads and waterways or by international air transport from Darlington.



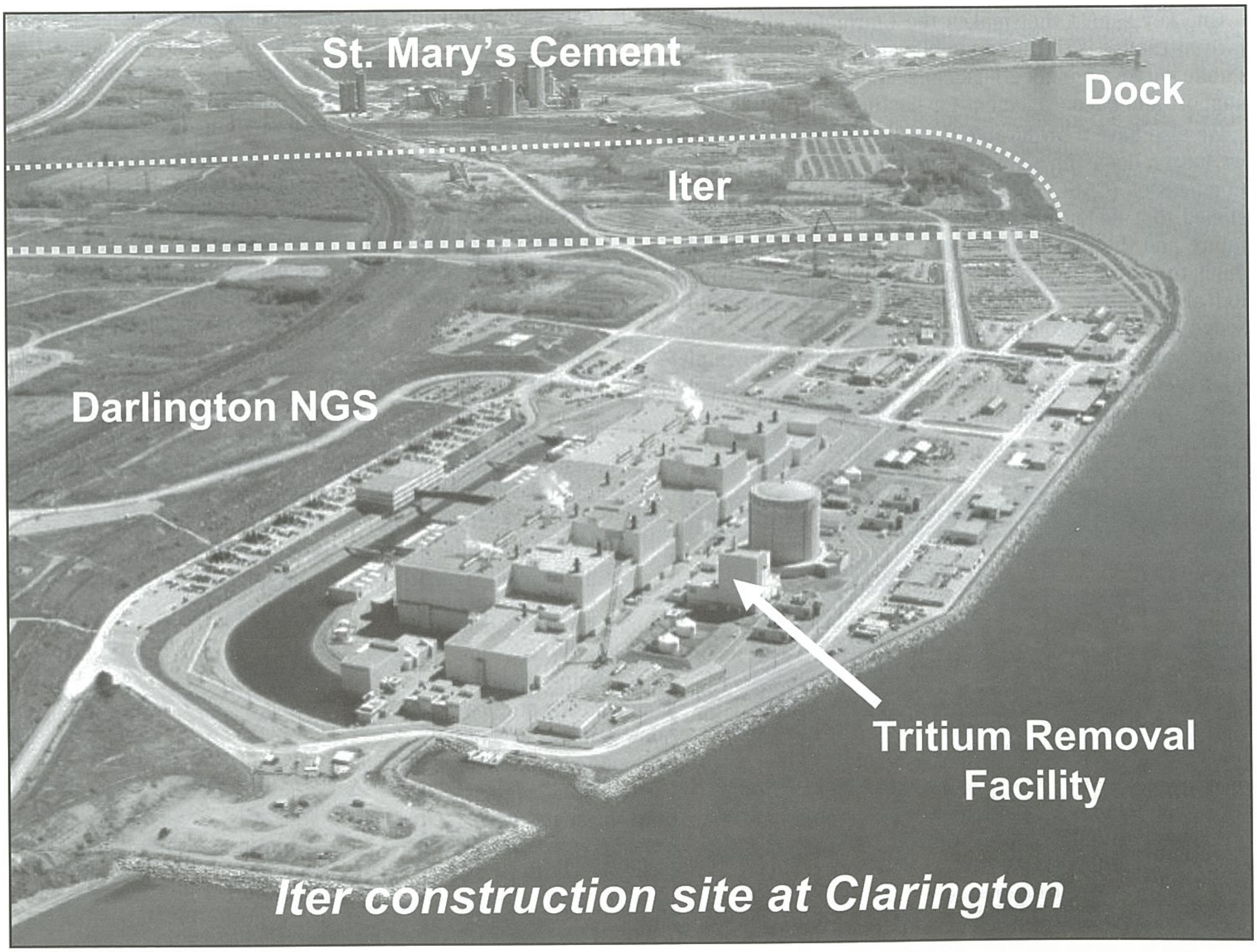
The group leading Canada's bid, Iter Canada, is a not-for-profit corporation formed in late 1997. It is a unique consortium of public and private sector Canadian interests involving four levels of government, the labour union movement, a number of universities and research establishments, and about 15 major Canadian companies, all of which have a contribution to make to the success of this project. (See Fig. 3) (visual "A consortium of stakeholders...")

As the host country, Canada would supply the buildings, infrastructure, site and supporting services. It will involve doing the things that we do well-we build huge buildings well, we build infrastructure well, we have the site and we know how to provide the services. Under the international collaboration, if the facility is built in Canada the other countries will essentially supply the high-tech components, which are then shipped to the site for assembly. For them it is more of a "Science" project, while for Canada it is an "Infrastructure" project.

Iter would be a continuation of the participating countries' scientific efforts to develop fusion. Japan currently invests about $700 million a year in fusion R&D and Europe in the range of $500 million. While they are not involved at the moment, the United States has a large fusion research effort and invests around $300-400 million each year.

So what are the benefits for Canada of this "Infrastructure Project"? They are tremendous and fall into three categories. First of all, the people-related benefits. One important aspect of the project that has captured the imagination of many people is that it would represent perhaps the largest single brain gain in Canadian history. About 250 of the world's leading physicists would move here with their families to work on the project under long-term contracts. The total range of jobs created by the project would employ many Canadians and would represent the equivalent of 68,000 person years.

The overall Canadian economy would also benefit, of course. An Ernst & Young study of the economic impact of hosting Iter in Canada has indicated that about $6.4 billion of debt reduction could result from this project, about $4.1 billion in federal debt and about $2.3 billion in provincial debt. The project would also drive a significant increase in foreign investment. Finally, there would be the technology benefits. Iter would give Canada access to advanced tech-



nologies, create spin-off companies, enhance Canada's R & D profile and give a boost to education.

While there are lots of benefits to Canada from hosting Iter, I believe there are many benefits to the other countries of bringing Iter here. (See Fig. 4) (Visual - "Our competitive advantages ...") In fact, if it were an objective decision, I think there would be no question that the Canadian offer is by far the best. One of our major competitive advantages is the tritium transportation issue I mentioned earlier. We think this is going to be a risk factor that other locations will not be able to absorb.

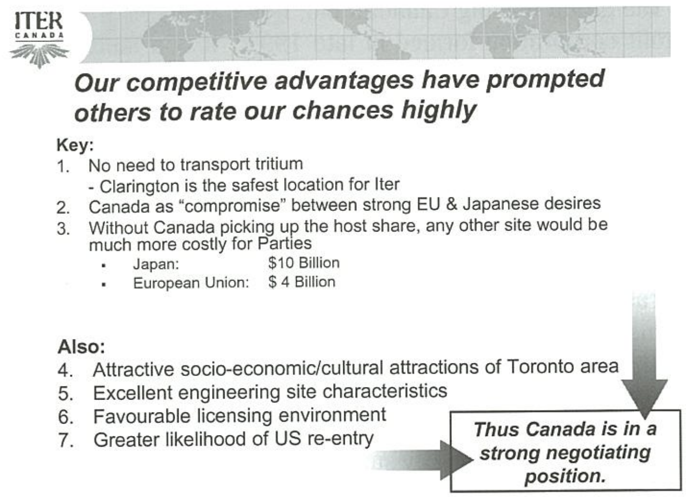
Canada also provides an enormous cost advantage. If the Iter project is built elsewhere, Canada will not be participating and Canada's contributions of site, infrastructure, etc. would not be realized. The total budget for Iter would have to be accommodated by the other parties. This would amount to an additional $10 billion to build the project in Japan, and about an additional $4 billion in France.

The conditions at the Clarington site are considerably more favourable than the agree-upon site requirements. Over 100 officials from the Iter countries have visited the site and uniformly agree "Clarington is technically the best site in the world for Iter."

One key aspect that makes the Clarington site particularly attractive is the strong public and community support. Public surveys and meetings consistently show very strong support and encouragement for hosting Iter.

We also have a favourable licensing environment, in that we have a licensing agency in the Canadian Nuclear Safety Commission (CNSC) that, with foresight, had actually envisioned that fusion might become an energy source of the future and therefore already has regulations in place that apply to fusion. We have formally initiated the licensing of Iter at Clarington and the CNSC has recently approved the scope for the environmental assessment. The first stages of the public information program have now been completed in eight communities in the area.

The Canadian contribution to the project would be substantial, with an offer of approximately a $3.5-billion net

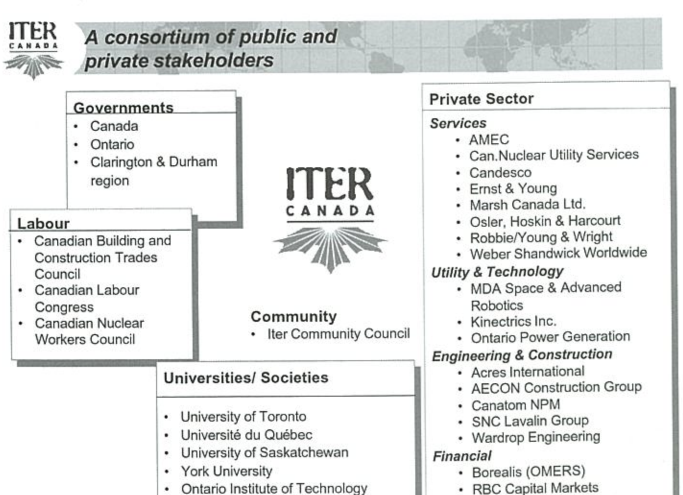



contribution from Canada's unique public/private partnership. This comes in part from Ontario Power Generation (OPG), which would supply the site and the tritium. In return, OPG would receive the contract for electricity. The private-sector share of the financing would contribute in excess of $1 billion, and the Ontario government has committed $300 million. A new organization, called Iter Canada Host Inc., is guiding Canada's bid and will take over the responsibilities of providing all the Canadian obligations for the construction and operation of the project in Canada.

The decision-making schedule for the project has been established, and the first two negotiations meetings have already been held, in Toronto last November and in Tokyo in January 2002. From the Tokyo meeting, we now have a draft international agreement, which will govern the way that Iter is structured, financed and operated by the four countries.

The third set of Negotiations Meetings was held in Moscow from April 23-24. Highlights included an indication by the European Union that Spain will offer a site for Iter. The next set of Negotiations meetings will be held in Cadarache, France from June 4th to 5th . It is expected that the selection of the preferred site for Iter will occur in the fall of 2002 and the Joint International Agreement to implement Iter will be completed by the end of 2002.

We are looking forward to coming back in a year's time and saying: "Canada has the project and we're off".



# The ITER Fusion Reactor and Its Role in the Development of a Fusion Power Plant

*by Adam McLean*[1]

*Ed. Note: The following paper was presented at the International Youth Nuclear Congress held in Daejon Korea, April 16 - 20, 2002.*

## Abstract

Energy from nuclear fusion is the future source of sustained, full life-cycle environmentally benign, intrinsically safe, base-load power production. The nuclear fusion process powers our sun, innumerable other stars in the sky, and some day, it will power the Earth, its cities and our homes. The International Thermonuclear Experimental Reactor, ITER, represents the next step toward fulfilling that promise. ITER will be a test bed for key steppingstones toward engineering feasibility of a demonstration fusion power plant (DEMO) in a single experimental step. It will establish the physics basis for steady state Tokamak magnetic containment fusion reactors to follow it, exploring ion temperature, plasma density and containment time regimes beyond the breakeven power condition, and culminating in experimental fusion self-ignition.

Motivation for development of fusion for power generation is ample. The world is in dire need of a safe, clean, sustainable source of power (Figure 1). In the future as we see it today, population growth continues its march upward, and energy demand, especially in developing countries, rises with only limited adoption of improvements in conservation and renewables. Fusion as a power source does not add to global climatic and human health consequences due to GHG and other pollutant release by burning of fossil fuels. With common Deuterium ($^2$H), and Tritium ($^3$H) potentially derived from Lithium ($^6$Li) as the only fuels, and Helium ($^4$He) the only waste, fusion does not involve the use of any fissile materials, and creates only short-lived activated materials (with $t_{1/2}$ typically <<100 years) requiring only above-ground Low Level Waste (LLW) class storage. A fusion reactor is inherently safe, containing typically <5 grams of fuel in the plasma at any given time, and requiring an extraordinary vacuum environment with fuel at temperatures of over 100 million degrees. Fuel is virtually unlimited, available to all nations. The facilities require minimal land use, and are not subject to weather variation, nor do they require energy storage. As well, advanced fusion reactions offer even greater benefit. Truly, there is no power source like that of nuclear fusion.

Research in containment of controlled nuclear fusion began in the early 1920's, primarily for military endeavours. At the historic 1958 Atoms for Peace conference in Geneva, though, declassification of nearly all research accomplished to that date, including details of the Soviet Tokamak *(toroidalnya kamera ee magnetnaya katushka* - torus-shaped magnetic chamber) designed in 1951, allowed the world to forge ahead in development of fusion energy with a level of cooperation unprecedented in any area even to today. Over 100 Tokomaks have been built in 30 countries since, shaping fundamental knowledge and confidence in technology suitable to capture fusion as a power source.

The ITER project itself began at the Geneva Summit in 1985, with a device designed to be capable of a steady-state, self-sustaining fusion reaction with a significant net energy gain. ITER Conceptual Design Activities (CDA) began in 1988 and were completed in 1990, carried out

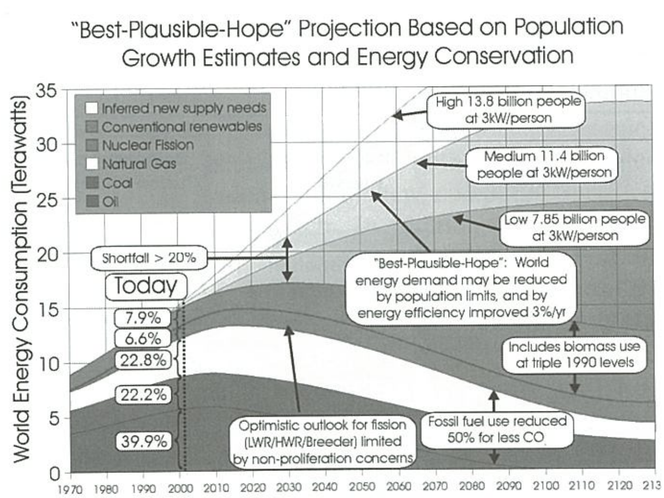



*Figure 1: "Best plausible hope" energy supply and demand projection based on UN population growth, world energy consumption, and energy conservation (1,2,3).*

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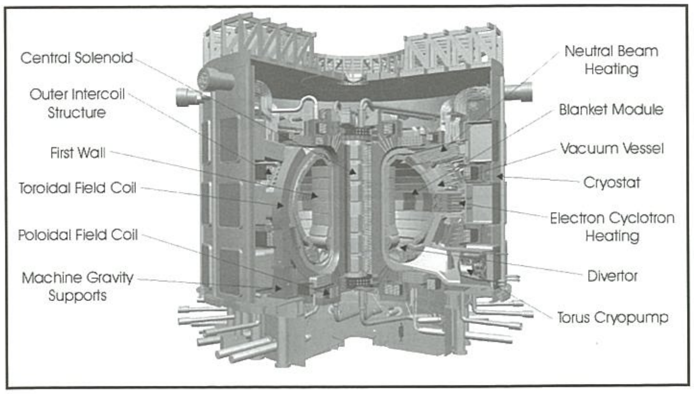


*Figure 2: The ITER-FEAT device and major components (4). Overall scale is 30 m tall, 15 m radius.*

*Table 1: Common fusion reactions (7).*

| Reactants | Branch | Products |
|---|---|---|
| $D + D$ | 50% | $\rightarrow T(1.01\ \mathrm{MeV}) + p(3.02\ \mathrm{MeV})$ |
| | 50% | $\rightarrow He^3(0.82\ \mathrm{MeV}) + n(2.45\ \mathrm{MeV})$ |
| $D + T$ | | $\rightarrow He^4(3.5\ \mathrm{MeV}) + n(14.1\ \mathrm{MeV})$ |
| $D + He^3$ | | $\rightarrow He^4(3.6\ \mathrm{MeV}) + p(14.7\ \mathrm{MeV})$ |
| $T + T$ | | $\rightarrow He^4 + 2n + 11.3\ \mathrm{MeV}$ |
| $He^3 + T$ | 51% | $\rightarrow He^4 + p + n + 12.1\ \mathrm{MeV}$ |
| | 43% | $\rightarrow He^4(4.8\ \mathrm{MeV}) + D(9.5\ \mathrm{MeV})$ |
| | 6% | $\rightarrow He^5(2.4\ \mathrm{MeV}) + p(11.9\ \mathrm{MeV})$ |
| $p + Li^6$ | | $\rightarrow He^4(1.7\ \mathrm{MeV}) + He^3(2.3\ \mathrm{MeV})$ |
| $p + Li^7$ | 20% | $\rightarrow 2\ He^4 + 17.3\ \mathrm{MeV}$ |
| | 80% | $\rightarrow Be^7 + n - 1.6\ \mathrm{MeV}$ |
| $D + Li^6$ | | $\rightarrow 2He^4 + 22.4\ \mathrm{MeV}$ |
| $p + B^{11}$ | | $\rightarrow 3\ He^4 + 8.7\ \mathrm{MeV}$ |
| $n + Li^6$ | | $\rightarrow He^4(2.1\ \mathrm{MeV}) + T(2.7\ \mathrm{MeV})$ |

jointly by the U.S., E.U., Japan and Russia under the auspices of the IAEA. Engineering Design Activities (EDA) commenced in 1992 and finished in 1998 resulting in a complete design. Financial constraints demanded a reduced-cost approach, though, and a second EDA period of 1999-2001 completed the current ITER-FEAT (Fusion Energy Amplifier Tokamak) design (Figure 2). With a final design accepted, the process of site selection is now underway, with Canada (Clarington), France (Cadarache), Spain, and Japan (Aomori and Ibaraki) under consideration. The choice for the preferred site is expected in June, 2002, with a final agreement set for December, 2002. In 2003, a 10-year construction period will begin, with a 3-phased operation schedule projected for 2012-2032, and decommissioning to follow. Progress with ITER is hoped to lead to DEMO in the early 2030's, and finally, a fusion power plant in by 2050 (Figure 3).

Although significant excess power (that is, greater than that required to create the conditions for fusion to begin, or a 'Q' value - the ratio of energy out over in - of > 1 or more than "breakeven") has yet to be produced, the past 25 years of fusion research especially has brought staggering improvement in fusion performance (Figure 4). Controlled fusion in magnetic confinement has stimulated a 100,000x ($10^5$) increase in the product of plasma density, temperature and confinement time achieved (known as the Lawson Criterion), and an even more impressive 100,000,000x ($10^8$) increase in fusion power production in the same period. ITER has been designed to continue this trend, able to sustain a Q > 5 for period of up to 300 seconds, and a Q > 10 for periods of at least 10 seconds (Figure 5). More precisely, for high power pulses, ITER will be capable of creating 410 MWth of fusion energy from 40 MW of heating power.

Once construction of ITER is complete, four distinct operational phases will commence. The first will be a three year period seeing only Hydrogen fuel at DT fusion relevant temperatures. An H-plasma allows initiation, and full commissioning of the tokamaks over 45 diagnostics and heating systems, cyclic current and magnetic field ramp-up/down, testing of the divertor configuration and disruption control, all without fusion occurring - i.e. a non-nuclear environment. Next, one year of operation with pure Deuterium fuel will see production of neutrons and limited T from DD fusion reactions (Table 1). The power produced will remain low, though, as the reaction rate profile for DD fusion is much lower than that of DT (~100x less at 10keV or approximately 100 million degrees - see Figure 6). Nonetheless, initial use of the heat transport and tritium processing systems will take place, testing of particle control (including fuelling, ash and impurity transport and pumping) and establishment of

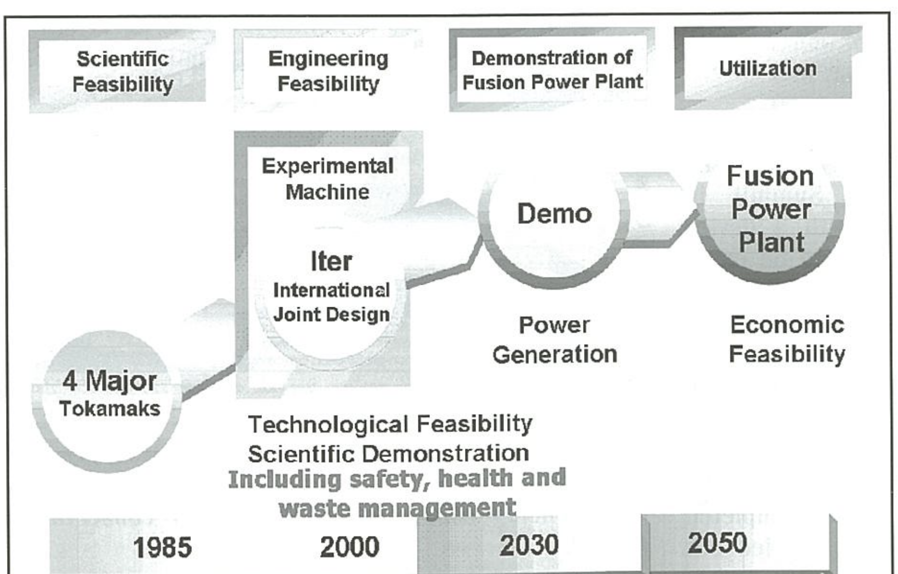


*Figure 3: The way toward fusion power (5).*

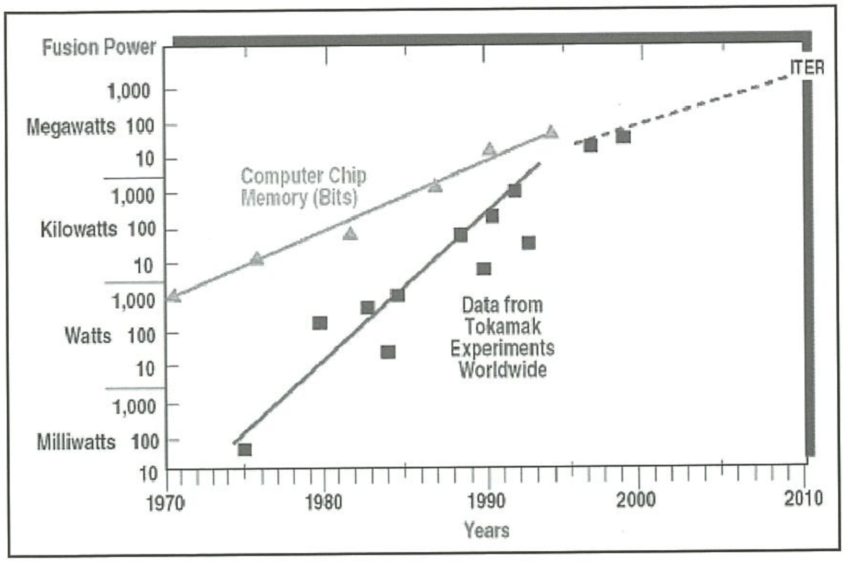


*Figure 4: Progress in fusion power output has been faster than memory chip bit density (6).*

a reference plasma (density and temperature profiles, divertor shaping, onset of edge localized modes) in steady-state operation will be made. The third phase, low duty DT, will see development of high Q (up to 10) and power (up to 500 MW) for increasing pulse lengths. At the end of this three year period, testing of DEMO-relevant test blanket modules will begin, as well as confidence in the capabilities of the remote manipulation system. In the final and longest phase, improvement in high duty DT fuelled fusion burn performance will be the focus. Testing of DEMO components and advanced materials with higher neutron fluences and exposure durations will be possible, as well as exploration of advanced modes of plasma operation well beyond those within reach of current devices. This may be further advanced by the addition of up to 110 MW of total heating power, and operation of plasma current up to 17 MA.

With these improvements, it is hoped that ITER will also allow for the possibility of reaching a more important goal, one that will be essential for a fusion power plant. For a deuterium-tritium plasma, once heating of alpha particles (the Helium nuclei product of fusion), not by external input but by the fusion process itself, is equal to the heat loss through the vessel walls and divertor, the plasma becomes self-sustaining and is said to be ignited, or burning. External heating can be turned off, and the plasma will continue to exist and induce fusion. With no heating (energy input), the Q factor ratio tends to infinity and the fusion process is controlled in steady state only by the fuelling rate to the torus.

To approach this condition, though, key issues currently understood only theoretically must be studied. These include:

- Effects of energetic alpha particles on plasma stability and turbulence
- Non-linear coupling between alphas, pressure driven currents, turbulent transport, Magnetohydrodynamic (MHD) instabilities, and boundary-plasma interactions
- Stability, control and propagation of fusion burn and ignition transient phenomena
- Techniques to optimize operational modes and profile regimes in toroidal fusion plasmas (Figure 7)

ITER is not the only reactor that has been designed with the goal of fusion ignition in mind (Table 2). Two other reactors, FIRE (US) and IGNITOR (Italy), intend to explore a steady-state fusion burn on a much more compact scale. This is attractive from both a cost, and specialization point of view, compared to ITER's broad approach. In addition, the superconducting device KSTAR, with operation in 2004 in Korea, will bring long-pulse experience that will contribute significantly to ITER operation.

From an engineering perspective, ITER has already led the growth of advanced technology in all its member nations. These include research in large, pulsed superconducting magnets, microwave and other plasma heating techniques, remote manipulator design, tritium handling, advanced computing, and control room technologies. Materials research focused on high-heat flux components, high-energy neutron damage, and reactor structure design has led to advanced

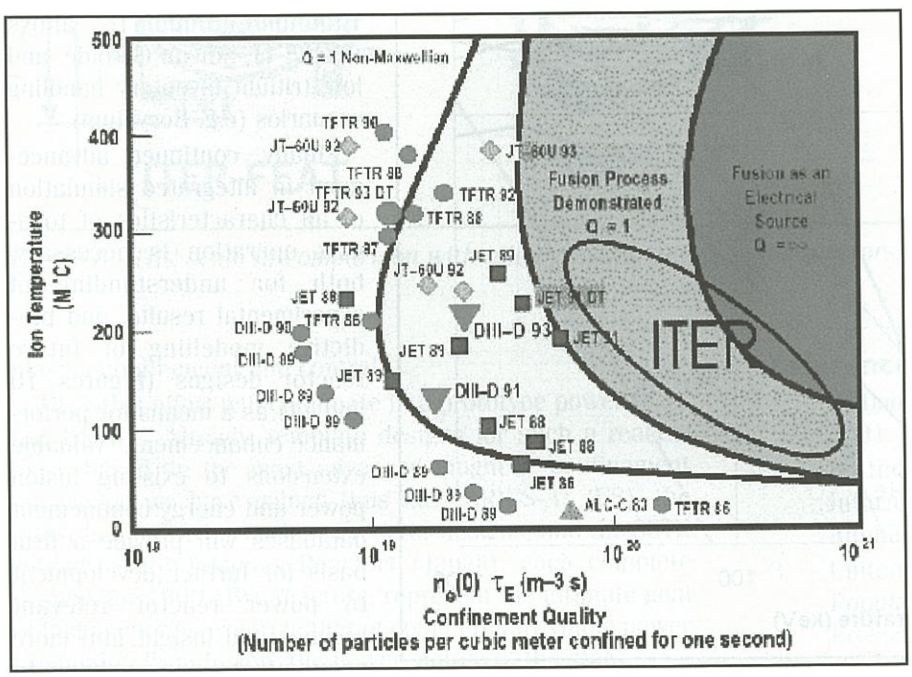


*Figure 5: Progress toward fusion as an electric power source.*

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Year of operation | - | 1983 | 1985 | 2004 | 2008? | 2008? | 2012 | 2030+ |
| Major radius, R | m | 2.96 | 1.6 | 1.8 | 2.0 | 1.32 | 6.2 | 5.1 |
| Minor radius, a | m | 1.25 | 0.56 | 0.5 | 0.525 | 0.47 | 2.0 | 1.3 |
| Cross-sectional area | $m^2$ | 5.1 | 2.1 | 1.5 | 1.6 | 1.27 | 21.9 | 8.7 |
| Vacuum vessel volume, V | $m^3$ | 95 | 21 | 17 | 20 | 11 | 837 | 308 |
| Plasma surface area | $m^2$ | 150 | 48 | 48 | 60 | 35 | 678 | 425 |
| On-axis toroidal field, B | T | 3.45 | 2.2 | 3.5 | 10.0 | 13.0 | 5.3 | 6.0 |
| Toroidal plasma current, $I_P$ | MA | 4.8 | 3.0 | 2.0 | 6.5 | 11.0 | 15.0 | 13.0 |
| Volume avg. plasma density, $n_e$□ $n_i$ | $m^{-3}$ | $2x10^{19}$ | $4x10^{19}$ | $1x10^{20}$ | $5x10^{20}$ | $5x10^{2}$<br>0 | $10^{19}$ | $10^{20}$ |
| Volume avg. electron temp., <$T_e$> | keV | 1.4 | 2.0 | 6.4 | 8.2 | 5.8 | 8.9 | 18.1 |
| Volume avg. ion temp., <$T_i$> | keV | 1.7 | 4.0 | 7.4 | 8.2 | 5.2 | 8.1 | 18.0 |
| Effective plasma charge, $Z_{eff}$ | - | 1.1 | 1.2 | 1.3 | 1.41 | 1.2 | 1.65 | 1.83 |
| External heating power, $P_h$ | MW | 25 | 24 | 15.5 | 30 | 11 | 40 | 37 |
| □ (Helium) - particle power, $P_□$ | MW | 3.2 | 0.002 | 15+ | 56 | 19 | 82 | 351 |
| Fusion power (thermal), $P_F$ | MW | 16 | 0.003 | 20+ | 220 | 25 | 410 | 1759 |
| Peak neutron wall load | MW/m$^2$ | 0.3 | 0.7 | 2.0 | 3.0 | 1.0 | 0.8 | 4.9 |
| Peak neutron divertor load | MW/m$^2$ | 0.5 | 2.0 | 3.0 | 5.0 | 4.0 | 5.0 | 14.7 |
| Energy multiplication, Q | - | 0.64 | 0.3 | 1+ | 10 | □ | 10 | 47 |
| Containment time, ð | s | 1.2 | 10 | 20+ | 20-60 | steady | 300+ | steady |
| Construction cost (2000 $CAN) | $B | 0.95 | 0.7 | 1.7 | 1.9 | 1.0 | 7.3 | 6.5 |

*Table 2: Detailed parameter comparison of current and future Burning plasma reactors (9-15).*

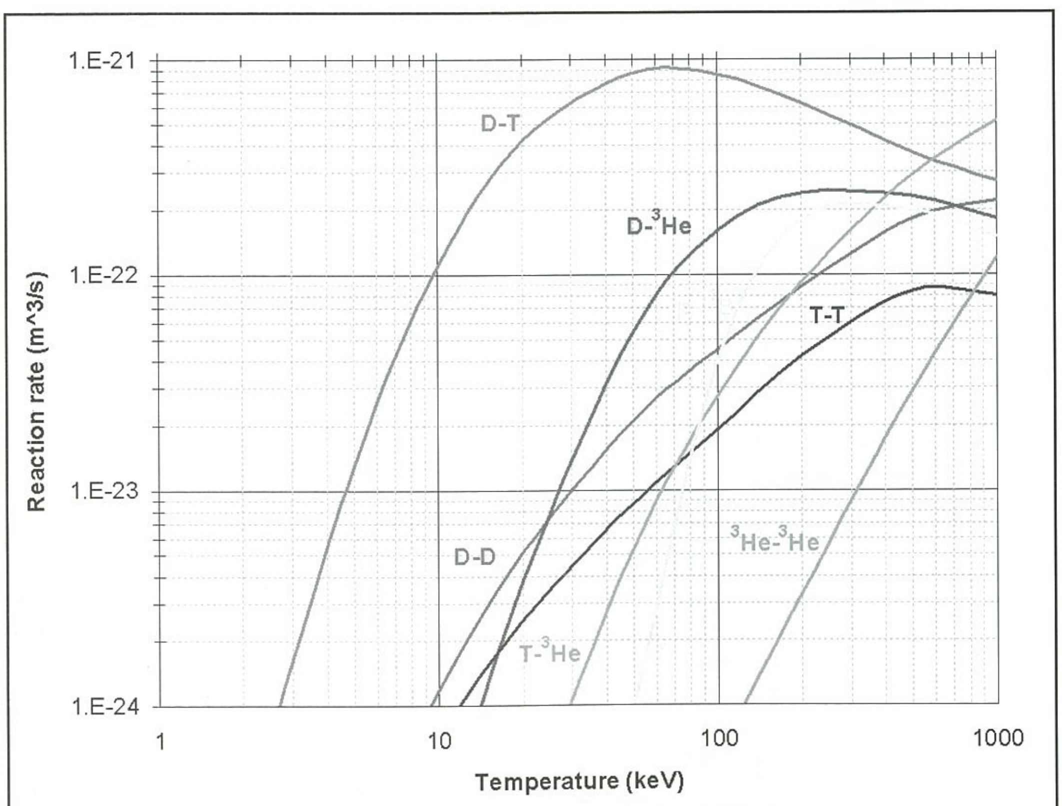


*Figure 6: Fusion reaction rate profiles (8).*

alternatives to current pyrolytic graphite armour and ferritic steel first wall materials (Figure 8, Model 2), including low-activation Vanadium/ Titanium/Chromium alloys (Model 1), Silicon Carbide, and low tritium inventory handling scenarios (e.g. Beryllium).

Finally, continued advancement in integrated simulation of all characteristics of tokamak operation is necessary, both for understanding of experimental results, and predictive modelling of future reactor designs (Figures 10 and 11) as a means for performance enhancement. Valuable extensions to existing fusion power and energy confinement databases will provide a firm basis for further development to power reactor relevant regimes and insight into more economical approaches to

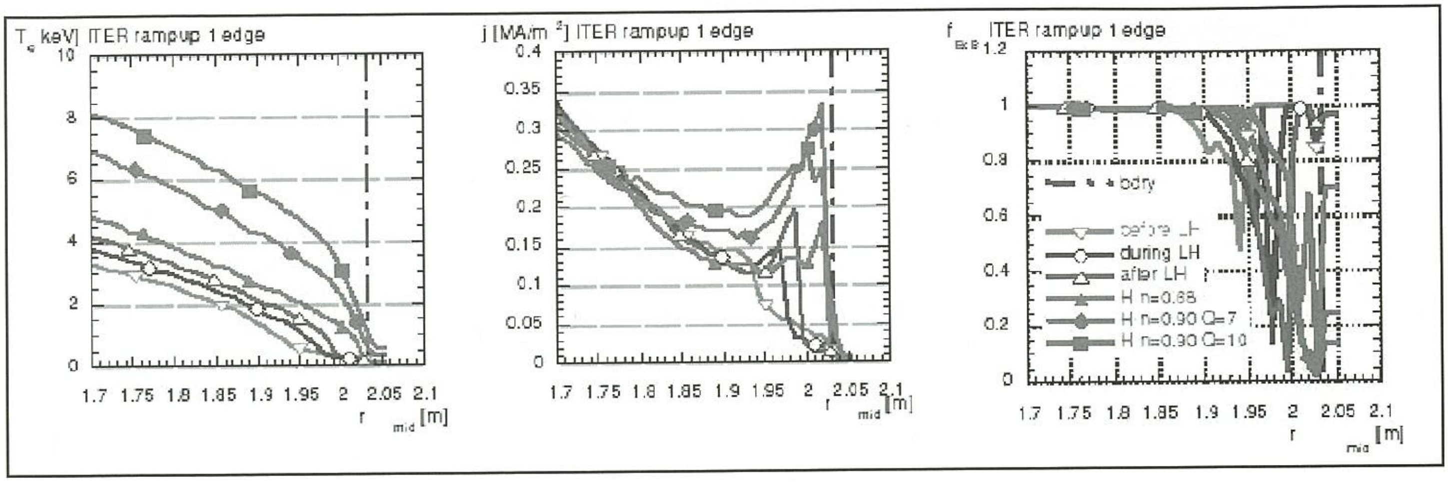


*Figure 7: Profile improvement with advanced confinement modes.*

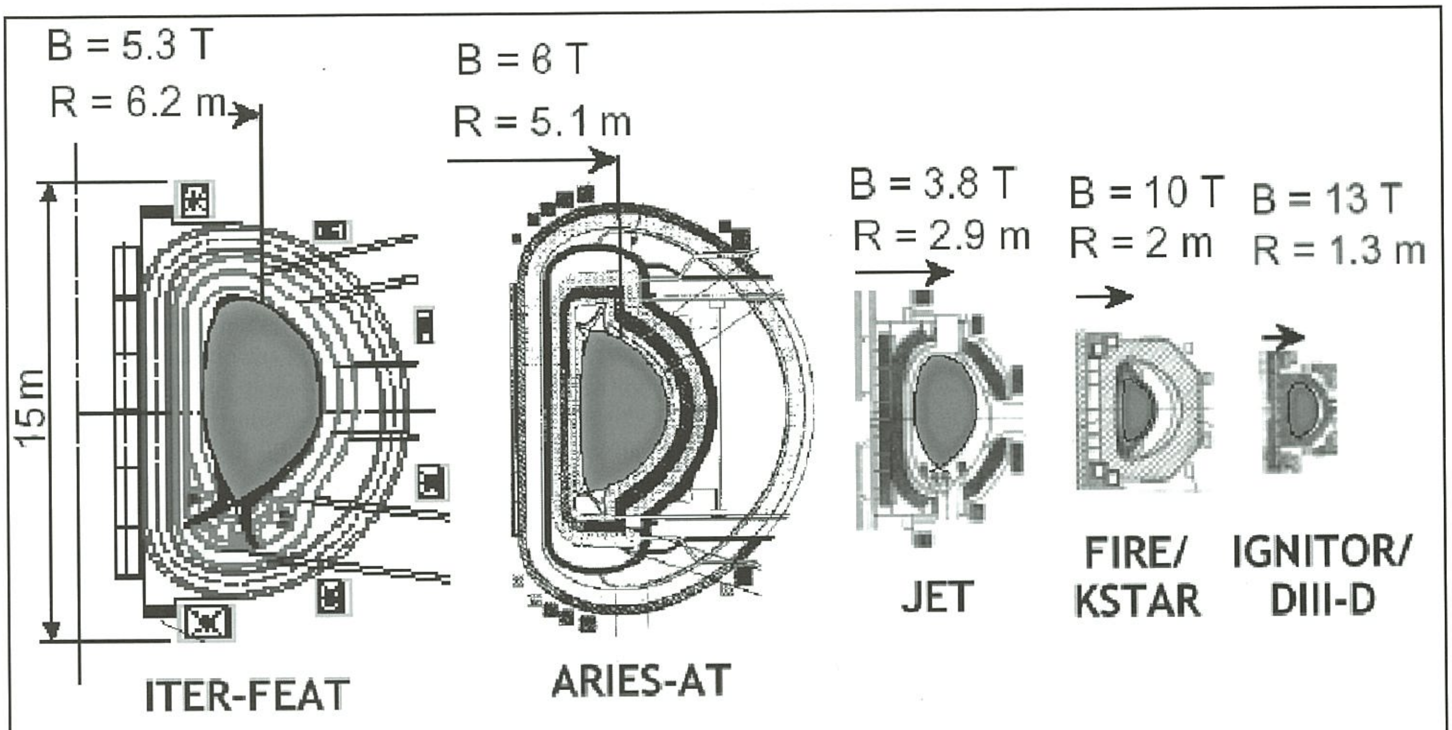


*Figure 8: ITER scale in comparison with other existing and planned reactors.*

plasma confinement and control.

All of this effort will culminate in a prototype power reactor, DEMO. Already, template designs for such a reactor exist, based on the most advanced magnetic confinement knowledge we have gained thus far. ARIES-AT (US), the latest in an evolving series of reactor designs, and the SSTR (Steady State Tokamak Reactor) (Japan), each complete designs for 1000 MWe reactors, represent the ultimate goal of fusion energy research; that of commercially viable power production from fusion, the power source of the stars.

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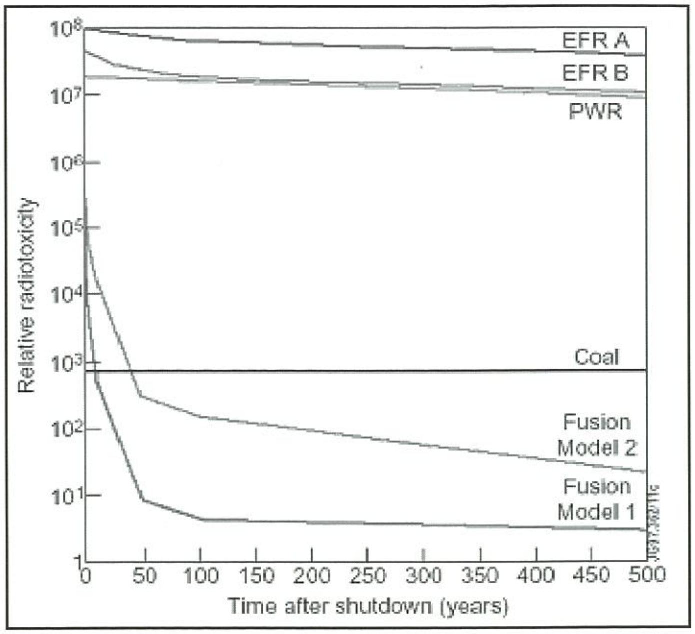


*Figure 9: Comparison of radio toxicity of power production options years after shutdown (16).*


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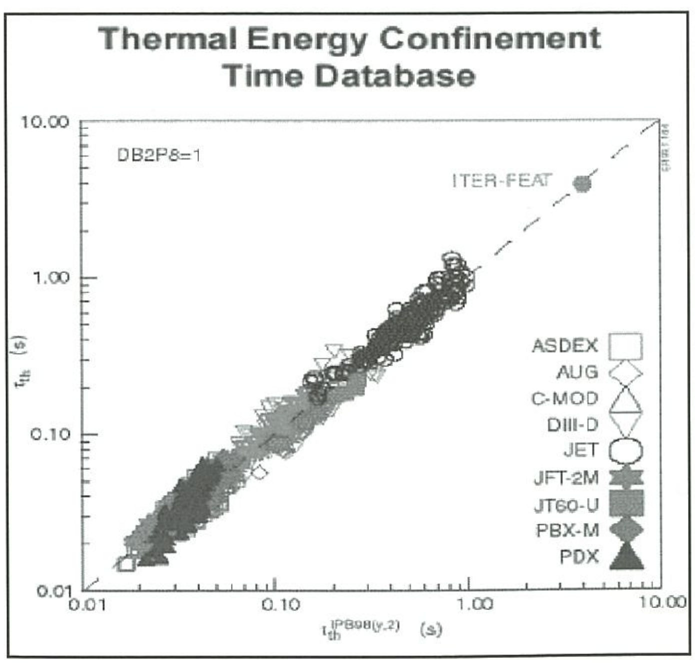
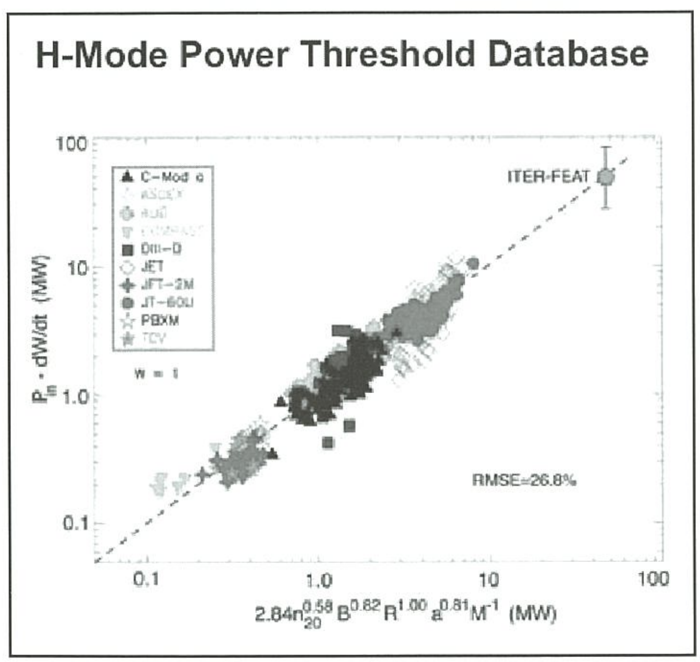



*Figures 10, 11: Empirical fit of main parameters of major tokamaks worldwide (17).*

# Winter Seminar

## - annual gathering draws largest attendance ever

The **Nuclear Industry Winter Seminar** for 2002 , held Monday evening, February 18 and Tuesday, February 19 in the Chateau Laurier Hotel in Ottawa, had over 300 attendees, including many politicians and senior government officials. This was the largest turnout in the history of the event.

Organized by the Canadian Nuclear Association (CNA) the event was co-sponsored by the Canadian Nuclear Society (CNS).

As has been the practice for several years, the Seminar began with an excellent reception held in the West Block of the Parliament Buildings, with the new Minister of Natural Resources, **Herb Dhaliwal,** acting as host.

The actual seminar began the next morning with opening remarks from **Allan Kupcis,** chairman of the CNA and **David Jackson** president of the CNS, followed by the first speaker, **Robert Van Adel,** president and CEO of Atomic Energy of Canada Limited. The crown corporation nature of AECL, Van Adel said, is an excellent platform for carrying out both commercial and public policy objectives. Over the past year, he reported, AECL had improved its relations with its shareholder (federal government) and restructured into an "enterprise model" to increase its business focus. AECL's vision is to be the top organization worldwide for nuclear products and services. He made a plea for all in the industry to dispel the negative myths about nuclear energy and closed by stating, "Nuclear is part of a sustainable energy system with an important role in the future global energy mix".

**Ron Osborne,** president and CEO of Ontario Power Generation Inc started by referring to the units his company had "de-controlled" over the past year; "Kinetrics" (the former Ontario Hydro Research) and "New Horizons" (the former information technology group). There will be more players, not fewer, in the electricity game, he commented. He went on to describe, with the use of some excellent illustrations, the electricity scene in North America, especially the US north east. After closing with a comment that unit #4 of Picker A would probably go back into service in the third quarter of this year he was asked about the repeated deferral of the re-start. "It is much easier to build new plants than refurbish old ones", he replied, and mentioned the exhaustive environmental review and the extensive requirements of the regulator (the Canadian Nuclear Safety Commission).

**Duncan Hawthorne,** CEO, Bruce Power, opened by referring to the impending competitive market and commented that the next three to five years were critical both for the industry and for Bruce Power. speaking of the benefits of a public / private partnership, he noted that Bruce 7 operated at 100% capacity in 2001. He spoke extensively of the need to develop a set of values to which all in the organization can subscribe.

After the break, **Tim Gitzel,** president and CEO of Cogema Resources Inc., launched a "high tech" presentation which included several video clips of Cluff Lake, McClean Lake, McArthur river and Cigar Lake mining properties. Half of their employees are native people from northern Saskatchewan, he noted. They are picked up by airplane, work a seven-day, 77 hour week, and then returned to their villages. Cogema is now part of the Areva Group of companies, a new French conglomerate.

**Grant Malkoske** opened with one of his impassioned stories about an Olympic athlete, Emma Robertson, who was cured of her thyroid cancer through treatments with radioisotopes supplied by his company, MDS Nordion. He then went on to describe the precarious situation with the 40 year old NRU reactor being the only source of supply of those isotopes. MDS Nordion supplies 60% of the radioisotopes used for medical diagnosis, he said, which are used in over 34,000 procedures every day. The need for the dedicated MAPLE reactors is critical, he said.

The just appointed vice-president of operations at the Canadian Nuclear Safety Commission, **Ken Pereira,** was the last speaker of the morning session. He began by bringing greeting from Linda Keen, the CNSC president, and repeated her earlier comment that their aim is to become one of the best nuclear regulators in the world. Pereira referred to the organization changes started last year, continued early in 2002 (which included his appointment) and would be completed ion April. The CNSC is moving to a risk based approach in compliance, he stated, and then warned that fees will be increased. *(See the General News section for more on the CNSC organization changes and licensing initiatives.)*

The luncheon speaker was **Dr. Luis Echávarri,** director general of the Nuclear Energy Agency of the OECD in Paris who spoke about "Nuclear Energy and Sustainable Development", based on the report the NEA issued in 2001. After reviewing the role nuclear power is now playing in the world he went on to point out the environmental advantages. "We cannot meet Kyoto [commitments] without nuclear", he stated. Other factors in the sustainability argument he noted were: uranium is abundant and has no other uses; there are rigorous [nuclear] regulatory regimes throughout the world; all external costs are included; and final disposal of nuclear waste is technically proven. On the social side there is a good institutional framework, research and development continues, workers and the public are well protected. In conclusion, he said, nuclear power meets all of the criteria for sustainable development. *(See Dr. Echávarri's full talk elsewhere in this issue of the* CNS Bulletin.*)*

After lunch, **Reid Morden,** chair, KPMG Corporation Intelligence Inc., (and former president of AECL) spoke on "Security of Canada's Critical; Infrastructure". This is the first time this topic has been on a CNA agenda, he commented. His is the one negative tone to the meeting, he added, and then warned that the cost of doing business has increased because of the events of September 11, 2001. Canadian energy sources are potential targets, he stated, and commented that Canada exports more energy to the USA than the middle east does. As a neighbour and friend of the USA Canada should be prudent and take precautions against attacks, he stated in closing.



Another change of pace was the talk by **Hugh Winsor,** a columnist with the Globe and Mail newspaper. Don't blame the messenger, he began, but look at the message. The public and the media do not distinguish between different parts of the nuclear industry, he commented, so a problem anywhere affects all. At the beginning of the nuclear program there was a generally positive attitude on the part of the public but then problems began; the Darlington debt; the cost of the Pickering refurbishment; the attitude of Ontario Hydro; Chernobyl; nuclear waste; and the on-going question of "why can't you sell more Candu without concessions. The industry must show that it is not a "sink hole" for public monies, he stated, and closed with the comment that he was sceptical about the claims for CANDU NG.

**Peter Barnard,** chairman and CEO of Iter Canada, reminded the audience of their bid to have the ITER project located in Canada. The bid was tabled in Moscow in June 2001 and discussed further in meetings in Toronto in November. Further negotiation meetings will be held in Moscow in April, in Cadarache (France) in June and Tokyo in September. Siting ITER in Canada would be the lowest cost option but both the French and Japanese want the project and are major contributors. He augmented his talk with excellent slides and videos showing the ITER design and the proposed project adjacent to the Darlington nuclear power station. *(Peter Barnard's paper is reprinted in this issue of the* CNS Bulletin.*)*

**Pierre Giroux,** a deputy director at the Department of Foreign Affairs and International Trade, and **Tom Gorman,** former CNA chairman and chairman of the CNA Task Force on Climate Change, reviewed the developments over the past year towards the ratification of the Kyoto Protocol. They noted that nuclear power had been essentially excluded in this round of Kyoto negotiations and the nuclear industry was now concentrating on "Kyoto 2", the period 2013 to 2018. Gorman stated that the CNA is arguing that, with its zero emissions, nuclear power can be part of the "sustainability" concept. Kyoto can be good for nuclear, he said in closing. *(Both of these short presentations are reprinted in this issue of the* CNS Bulletin.*)*

**Bill Clarke,** president and CEO of the CNA, avoided trying to summarize the day's presentations and thanked all of the speakers for their excellent contributions. A warm round of applause showed that the audience echoed his sentiments.

All of the presentations are accessible on the CNS Web site < www.cna.ca >.

# The Kyoto Protocol and Nuclear Power: Two Views

***Ed. Note:*** *At the Nuclear Industry Winter Seminar held in Ottawa, in February 2002, two somewhat differing views of Canada's and the Canadian nuclear industry's positions on the Kyoto Protocol were presented. Both are printed below.*

## Past and Future Directions in Climate Change Policy

*by Pierre Giroux*[1]

The Kyoto Protocol is a very complex issue and there has been much in the press. I would like, therefore, to concentrate on giving you an idea of where we are going in the future .

In order to see where we are going on this process, we have to see where we came from. To understand where we come from, we have to understand that there is a science-based problem -namely climate change - that was identified in the mid-1980s and led to the first fundamental process, the 1992 Rio Convention, which produced the United Nations Framework Convention on Climate Change [UNFCCC].

That Convention gave a general outlook of what we should do to address climate change, but it did not give us the specific tools on how to tackle it. So the 189 countries that were parties to the Convention decided that we should have a stronger tool to address climate change. At that point, the architecture of what we now call the Kyoto Protocol was decided. It's important to understand that this was, fundamentally, a partial architecture, in that we agreed that industrialized countries would have to take the lead to reduce their emissions before the rest of the world, the developing countries, would take on commitments.

The question was: how should we reduce the emissions? This was the subject of a huge debate in 1994-95, when we discussed the fundamental architecture. One position held that we should have only domestic policies and measures. Another position, shared by Canada, held that we should have also flexibility in trying to find the lowest marginal cost for reductions, bearing in mind that the problem is not really the emissions in any particular country, but rather the accumulation of greenhouse gas emissions globally. And this debate gave us, in 1997, the Kyoto Protocol.

The Kyoto Protocol gave us what I would call a precise blueprint for giving industrialized countries general targets, and left out developing countries. For example, we agreed, that we would collectively reduce our emissions levels -5.2% from 1990 levels. But this gave a very broad "portfolio" of reductions through the system.

For example, Canada committed to -6% in reductions, and the United States to -7%, while some countries, like Iceland, went to a plus 10%. But overall, countries would collectively reduce their emissions.

This is where the process becomes interesting. What would the content of these emissions be, and, what is the link with nuclear? At that point in time, the question was:

— How can we actually get emissions reductions in developing countries to a process called a clean development mechanism and actually get those emissions reduced in developing countries and then repatriate the emissions to

1 Deputy Director, Policy Climate Change and Energy Division, Department of Foreign Affairs and International Trade.

the countries that have commitments?

This question started the famous debate on what to include as acceptable types of projects under the joint implementation-which are the projects you do in other countries that have commitments and the projects you do in countries in which you don't have commitments. So we had these negotiations, which started in 1997 and extended to 2001. It was only last November that we finally terminated one part of the negotiations, the part surrounding the rules in which we would implement the Kyoto Protocol.

But in parallel with this process, we continued the negotiations and the implementation of the original 1992 Convention. This part of these two pillars-the ones linked with the original Convention and the ones linked with the new "son" or "daughter" of the original Convention, called the Kyoto Protocol-came forward in 2001. What does this mean?

It means, on one side, that we now have a deal that allows us to actually move forward on the Kyoto side and eventually ratify it (for ratifying we need a certain number of countries actually agreeing to implement the Protocol). But it also means that in parallel we will continue the process. This process, of the UNFCCC is the one that deals essentially with everything linked with developing countries fundamentally. It is a package through which we will try to improve the capacity of developing countries that eventually take on commitments in the future.

What did we get with the Kyoto Protocol? We got mechanisms, we got agreements on how to actually calculate in our inventories things like the natural capture of the carbon. And we got an important element, which is a process that will lead us to the next step of discussions.

Where does nuclear fit into this? There is a perception that nuclear was excluded from the Kyoto Protocol and that it's the end of the line for nuclear in this process. This is not the case. First, nuclear energy is part of the inventory for domestic reductions, which means any nuclear process that is done in a country that is under the Kyoto Protocol that has obligations domestically is still counted in the inventory. So any new plants that would be created, such as the one approved recently in Finland, would have to be calculated against that country's levels of emission.

In addition, it's important to remember that although we were not successful (and Canada fought very hard on this) to have the parties agree that the nuclear projects would be capable of generating international credits, we don't have outright rejection of nuclear but a refrain-from-use for the first commitment period.

What does this mean in practice? It means that the process under Kyoto is not finished. We are already starting to negotiate the second commitment period, which will start in 2013 for the following five years. To get to this new agreement, which I'll call "Kyoto 2," we have to start negotiations today. By 2005, which is the official start of the second period of negotiations, we have to determine the new architecture of the future discussions. Those will go on until 2008, by which time we hope to have completed the negotiations for the second commitment period, which will lead us in the future. All this means that we still have the opportunity to restart our discussions about the role of nuclear.

So, fundamentally, we are on two tracks. On the first track we will pursue the UNFCCC process, which will bring us to 2005, 2008, and so forth. The second track will lead to ratification of the Kyoto Protocol, for which we need 55 countries, representing 55% of emissions of developed countries. This process is already under way. The European Union has made commitments to ratify by June. The other developed countries are now studying the Protocol to see if they can meet the commitments under the new Kyoto rule. Hopefully, by the time of the Johannesburg Summit next September, we will have a clear notion of whether or not we can actually enter the Kyoto Protocol into force, in order to continue the process of emissions reductions.

In conclusion, we are now in a process of trying to define a new strategy that will allow all developed countries to begin to define their positions. We have three years of what we could call conceptual discussions on the future architecture of the process. So the process is far from finished. In fact, the process will probably continue for the next 50 years or so, because the Convention itself is an evolving document. This is why it's called a Framework Convention. It is not a finished product; it is a product that has to evolve as we go along and as science gives us more background on what we are actually dealing with in climate change.

Nuclear has perhaps had a slight setback for one part of the equation, which is for patriating projects in developing countries, but it is by no means the end of the road for these discussions. In the meantime, the process is still fully open for national projects.

# Canada's Nuclear Industry and Climate Change Policy

*by Tom Gorman*[2]

### Overview

The negotiators at the Conference of Parties to the Kyoto Protocol (COP 6.5) concluded in Bonn last summer to details regarding the international treaty to reduce greenhouse gas emissions. Included in the agreement was a package of mechanisms to allow the creation of credits and the trading of those credits to other nations party to the Treaty. The final legal text of the Treaty was agreed to at COP 7 in November, 2001.

One of the clear consequences of the COP process was that nuclear energy was a clear and singular casualty of the negotiating process. It, and it alone, was excluded from

2 Chairman, Climate Change, Canadian Nuclear Association

being a source of generating credits for purposes of the Kyoto trading mechanisms, Joint Implementation or the Clean Development Mechanism.

To understand how this occurred, we must first understand that the negotiators at COP 6.5 were operating under a system of considerable political pressure. For the negotiators, it was necessary to achieve an agreement for the following reasons:

1. To meet the timeline of the Buenos Aires Plan of Action that requires a review of achievements by August, 2002;
2. To satisfy rising public expectations that action would be taken on global warming;
3. To ease increasing tension within the ENGO community; and perhaps most importantly,
4. To demonstrate that the United Nations process could not be halted by the withdrawal of the United States.

Given that the ability of nuclear power to avoid the production of greenhouse gases economically is uncontested, the decision to exclude nuclear power seems at first glance to make no sense. However, there were a number of political and economic factors that led to its exclusion, which factors the world's nuclear industries and their supporters in government were not strong enough to overcome. These reasons are:

1. Nuclear power was an easy target, because, as an industry, it is not sufficiently large that any major nation is damaged extensively economically if nuclear power was excluded from the Kyoto mechanisms. Only a few nations are engaged in the export of nuclear goods and services, and for only a few of those nations is nuclear power a large part of their exports.
2. Nuclear power has not needed to be a high priority for many countries for nearly 30 years because of low or declining prices of fossil fuel and therefore no motivation to curtail its harmful emissions. Consequently there has been little pressure for reasons of security of supply or rising real fuel costs to encourage alternative energy sources like nuclear power.
3. The Kyoto negotiating process witnessed the formation of a powerful antinuclear coalition: the negotiators from the EU environment ministries with the G-77 nations led by Saudi Arabia, which was opposed to nuclear power for commercial competition reasons. The former are often under the direct control of the Green Party coalition partners in the national government. In the latter case, the opposition of Saudi Arabia was commercial, based upon the perception of nuclear power as a competitor. Small states within the G-77 were opposed to nuclear power in part because they felt that nuclear power would constitute such large potential sources of trading credits that the smaller projects which they might attract would be ignored.
4. The withdrawal of the United States from the Kyoto negotiating process at a relatively late stage robbed the Umbrella Group nations of their natural leader and its predominant influence over the negotiations.
5. Nuclear power could be excluded from the Kyoto agreement because for many countries there has been little consideration thus far of the measures that would be necessary to implement the agreed emission cuts and the costs that would ensue. It is also apparent that most countries have not consulted with business and industry groups to the extent that the Canadian government has, and thus many of the Kyoto negotiators may not have had a complete grasp of the requirements of the commitments that were being made.

## Current Situation

The limitation of nuclear power in the Kyoto agreement only applies to international trading mechanisms. Nuclear power will continue to be necessary for many countries to meet their Kyoto emission quotas. In fact, the consequence of the exclusion of nuclear power from the trading mechanisms means that the eventual market for emission credits is likely to be smaller. This in turn means greater emphasis on domestic activity to reduce emissions.

Furthermore, the Kyoto agreement only affects the first commitment period of the Treaty from 2008 to 2012. After that, all of the relatively easy reductions will be gone, and countries will tend to face much greater difficulties to achieve the second commitment period with its anticipated more stringent requirements. There may well be a reassessment of the exclusion of nuclear power from the Kyoto agreement with respect to the second assessment period.

However, even if there is no removal of the exclusion of nuclear from the international trading mechanisms, nuclear power will remain and likely grow in importance for domestic emission reduction.

In light of these domestic and international considerations, the Canadian Nuclear Association is taking steps in two key areas to ensure that nuclear power remains part of Canada's solution to global warming.

1. It is probable that any domestic program to control emissions will result in the creation of a domestic emissions trading system. Canada is short of meeting its target by approximately 100 million tonnes of carbon dioxide. The CNA is developing and implementing measures to ensure that the role of zero-emitting sources of energy, including nuclear, hydro-electric, wind and solar, are recognized in any resulting trading system. The purpose is to ensure that the market for emission credits does not send distorting signals biased against zero-emitting sources.

2. Internationally, any recognition of nuclear power must come with an understanding that nuclear power can be an important contributor to sustainable development. This program is being conducted on a collaborative basis with our partners in other countries through international organizations such as the World Nuclear Association. The purpose of this measure is to ensure that nuclear power is reconsidered for inclusion for the second commitment period. Most important is that the Commission on

Sustainable Development, in its recommendations to the World Summit on Sustainable Development, includes nuclear as a sustainable energy technology.

## Conclusion

At this time, the countries party to the Kyoto Treaty are now contemplating the prospect of ratification. A number of business groups and industries are now indicating some need for caution or even outright opposition to ratification of Kyoto, citing a range of economic costs or regional economic effects as potential consequences.

For Canada's nuclear industry, even a poor treaty to limit greenhouse gas emissions is better than none at all. Given the large contribution that nuclear power can make to reducing carbon dioxide emissions economically, Kyoto is a treaty that can only benefit our industry irrespective of nuclear power being excluded in the short term from the international trading mechanisms.

It is in that light that the programs of the Canadian Nuclear Association are designed to ensure that Canada's nuclear industry will have a growing role to play, both here at home and around the world, to reduce the emission of greenhouse gases while producing reliable, low-cost electricity, and to enhance security and diversity of energy supply in industrial and third world nations alike.

# Nuclear Energy and Sustainable Development in the OECD

*by Luis E. Echávarri*[1]

***Ed. Note:** Following is a slightly edited version of Dr. Ech·varri's notes for his luncheon address to the CNA/CNS Nuclear Industry Winter Seminar held in Ottawa, February 18, 2002.*

I am very pleased to have the opportunity to provide an overview of the findings of the OECD Nuclear Energy Agency (NEA) related to nuclear energy and sustainable development.

As you know, sustainable development is a relative concept which is open to some interpretation. In our work at the NEA, we have tried to identify the main criteria that need to be considered when assessing the sustainability of nuclear energy. This work has proven to be very useful for governments in their own policy discussions. These criteria are described in detail in the NEA report entitled Nuclear Energy in a Sustainable Development Perspective, which is available free of charge on the NEA website. Of course, the findings in the report do not prejudge the policies of individual Member countries or, due to their different economic, environmental and social situations, the conclusions they may draw.

If you were to ask the question, "Is nuclear energy sustainable", the answer would depend on the person you ask. At the NEA, and in line with OECD work on sustainable development, we have highlighted the relevant criteria according to their economic, environmental and social aspects.

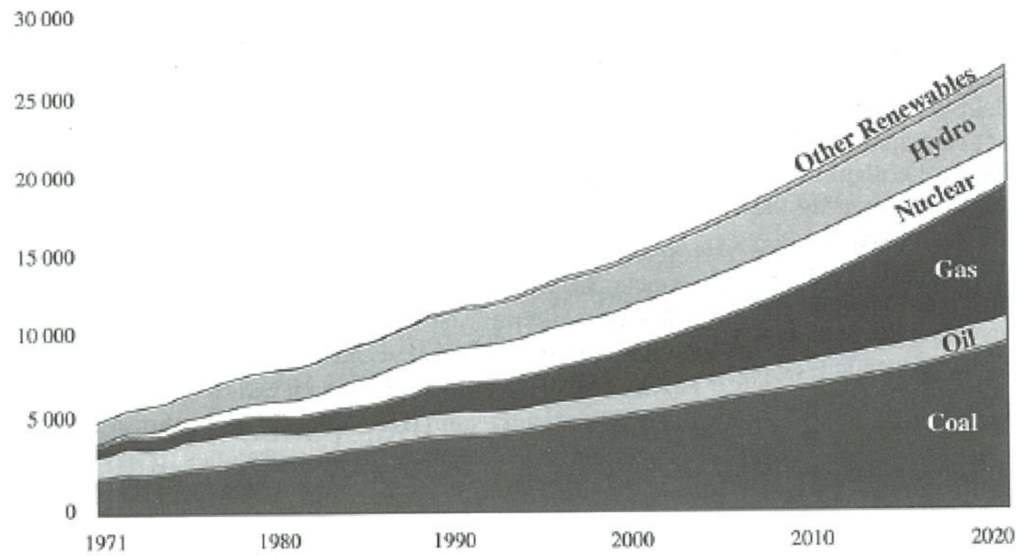
## Nuclear energy and the economy

Energy is one of the motors of economic development and nuclear energy is a part of it. Today, nuclear energy represents 16% of total electricity produced in the world. This electricity is produced by some 435 nuclear power plants, with an accumulated experience of more than 10 000 reactor years of commercial operation. Most of this nuclear energy is produced in the OECD countries: 350 out of the 435 units are located there, where they represent 24% of total electricity production. OECD nuclear power plants have already accumulated more than 8 000 reactor years of commercial operation.

As for any type of energy, ideally subsidies should be avoided. While historically

1 Director-General of the Nuclear Energy Agency of the Organisation for Economic Cooperation and Development, Paris

## World Electricity Generation, 1971-2020




nuclear energy had been subsidised by governments, the situation has changed and this is no longer the case. Some concerns were also voiced that nuclear energy should be operated by public companies, or that if operated by private companies it would be difficult to change ownership because of the responsibility that it implies. It has recently been demonstrated that it is feasible to change ownership of nuclear assets and still continue with a very high level of operation. There are even countries where foreign companies have already taken responsibility for nuclear power plants.

Despite concerns about competitiveness in the deregulated markets, experience has shown that existing nuclear power plants are competing very well. In fact, in many countries electricity produced by nuclear power plants has proven to be a very competitive means of producing electricity, especially since once fixed capital costs have been amortised or even incurred, operating and fuel costs are comparatively very low.

Nuclear energy may be even more competitive than many statistics show, as it is more advanced than most other energy sources in internalising external costs, which is essential if reliable cost comparisons are to be made. One example of the internalisation of external costs is the inclusion by most OECD countries of the cost of decommissioning and the disposal of high-level waste in the price of the electricity produced by nuclear power plants.

At present, new nuclear power plants remain very capital intensive and nuclear energy often has difficulties in competing with natural gas. Of course its competitive situation could evolve in the future, depending on the prices of other sources. One of the keys to the future competitiveness of nuclear energy will be the significant reduction of capital costs. This is one reason why some OECD and non-OECD countries are studying new technologies, especially Generation IV technologies, which try to considerably reduce the initial capital investment as well as to enhance safety, reduce the generation of high-level waste and make reactors more proliferation-resistant. If these new technologies were economically competitive, that would be a significant breakthrough from a sustainable development perspective. The NEA is providing support to the Generation IV initiative.

Capacity factors, or the percentage of time plants are operating at full power, are also a key determinant of the economics of nuclear power. With the maturing of the industry, capacity factors have increased significantly and are now reaching almost 90% in most OECD countries. In addition, the power ratings of many plants are being increased. The stability of this form of energy makes it very advantageous as a base-load source of electricity.

Another key economic factor is how long plants operate. In two OECD countries, the UK and the US, licences have begun to be extended beyond the 40-year lifetime originally planned, increasing to 60 years in the case of the United States. The prospects are that this approach will be extended to other countries and a very significant number of nuclear power plants could continue operating for longer periods than initially intended. This will help offset the high capital investment in the plants.

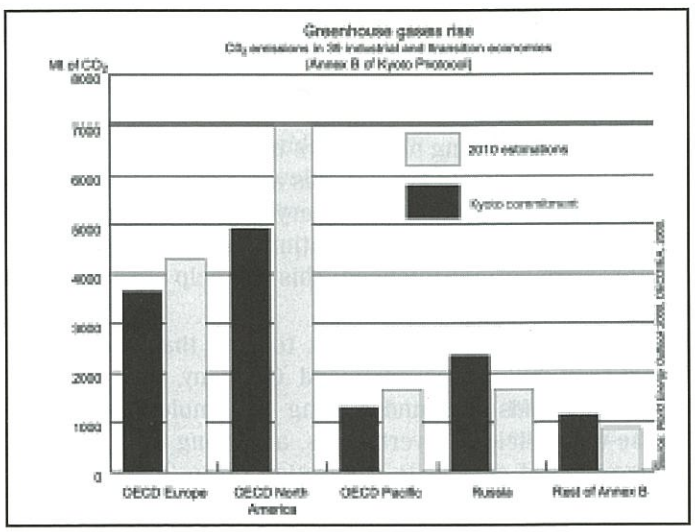
However, it is also important to note that some other countries, such as Sweden and Germany, are following opposite trends and undertaking the implementation of phase-out policies. Nevertheless, according to IEA projections of world electricity generation up to 2020 (recently published in the *IEA World Energy Outlook 2000)*, although it is expected that the overall percentage share of nuclear energy will somewhat decline, global output is projected to remain roughly the same.

A breakdown of these figures into the three main geographical areas of the OECD shows that in OECD Europe there will likely be a certain decrease in nuclear power generation because of phase-out policies and the dismantling of some nuclear power plants between now and the year 2020. Only Finland is considering a new plant at this moment, with France announcing its intention to replace some of its existing reactors with new ones in the future. For OECD North America, a minor decrease is also expected, but this may be partially offset by the life extension of a significant number of units. In the OECD Pacific area, clear expansion is foreseen due to Japanese and Korean plans to continue building nuclear power plants. One may thus conclude that nuclear energy will continue to make a significant contribution to electricity generation in the years to come, even if no account is taken of its merits in terms of sustainable development.

In addition to the contribution of nuclear energy to the economic and technological development of OECD Member countries, we should note that nuclear energy has contributed significantly to three important elements in energy policy. Firstly, it is clearly contributing to the **diversification** of energy sources, which helps towards ensuring the stability of market prices. It also contributes significantly to **security of supply,** since its technology and resources are available in OECD countries. Finally, regarding **protection of the environment,** at this very moment the electricity produced by nuclear power plants is avoiding substantial quantities of $CO_2$ emissions.

## Nuclear energy and the environment

As nuclear energy is not based on a combustion process, it does not produce stack emissions of CO2, the main greenhouse gas. If nuclear energy had to be substituted by fossil fuels, $CO_2$ emissions for the energy sector would increase by 8%.




If you take into account that the Kyoto Protocol is looking for a reduction of $CO_2$ and five other greenhouse gases by 5.2% (from the 1990 emission levels) by 2010, it soon becomes obvious that nuclear energy's contribution to reducing greenhouse gases and avoiding global warming is comparable to that foreseen in the Kyoto Protocol. This is all the more important to the extent that current projections estimate that $CO_2$ emissions in the year 2010 will be surpassing those of the Kyoto commitment.

Existing nuclear processes are based on uranium, which is an abundant natural resource for which there is no other use. The use of uranium also means, by extension, that other natural resources are being saved.

The emission of radioactivity from nuclear power plants to the atmosphere is very low in comparison with natural background radioactivity, representing only a very small fraction of the radiation we are exposed to in normal, day-to-day life.

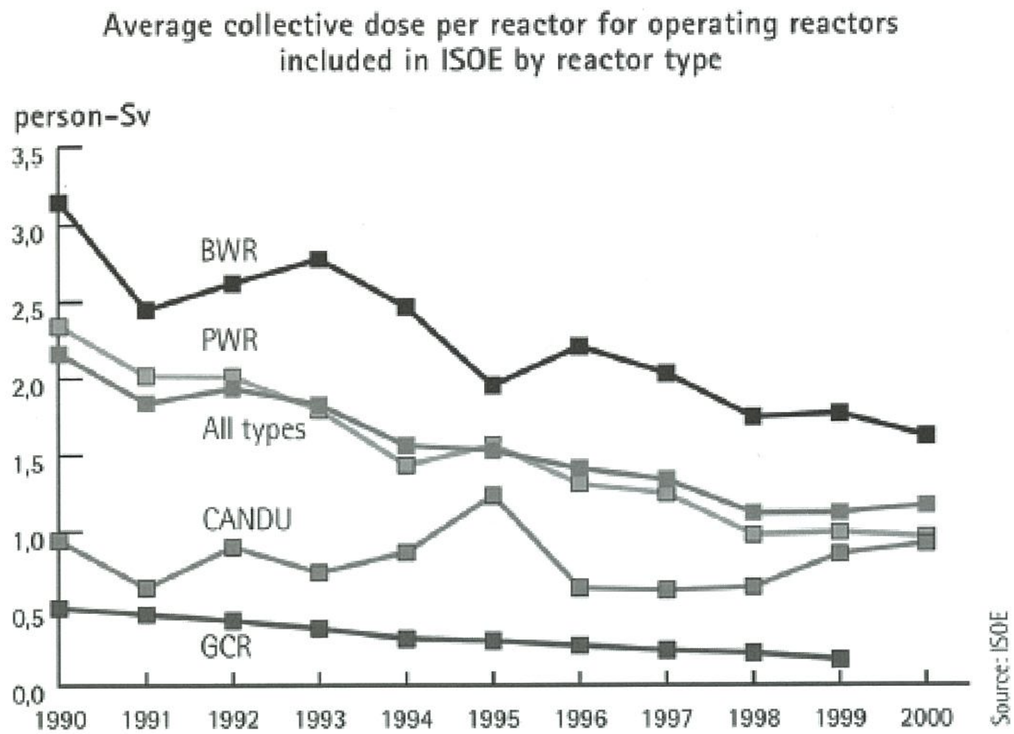
In order to protect the environment from accidental emissions of radioactivity, OECD countries have established very rigorous regulatory regimes and independent regulatory bodies providing for control over the safe operation of plants. There are also national and international regimes of nuclear third-party liability, which establish the rules for compensation in case of accident.

Regarding high-level waste, while the amount of this waste is very small in comparison with wastes produced by other electricity sources, and it can be further reduced by partitioning and transmutation techniques, it is clear that its isolation from the environment is extremely important due to its radioactivity during very long periods of time. While there is no immediate urgency in establishing final repositories for spent fuel and high-level waste, from ethical and sustainable development perspectives, a final solution for this type of disposal should be found. Plans for the final disposal of high-level waste should be made through coherent policies, and with public participation, which ensures that society understands and supports these solutions. From a technical point of view, the necessary technology for safe, deep geological repositories is available.

A first deep geological repository for high-level waste from military uses began operation in 1999 in New Mexico, USA. The deep geological disposal concept being used in New Mexico is also being considered in other countries for the disposal of spent fuel and high-level waste from nuclear power plants. Some of them, such as Finland, are very advanced in preparing the implementation of a final disposal scheme. In that country, the scheme has also secured government approval. In the United States significant progress is being made with the Yucca Mountain Project, although important steps remain. The OECD/NEA has organised, together with the IAEA, an international peer review of the Yucca Mountain Project, the report of which has just been presented to the US Government. We should note that the success of these projects is depending not only on technical issues, but also on public perception; here in Canada, you are very well aware of this because of your own experience. Similar approaches, combining technical and social aspects, will need to be considered for the decommissioning of nuclear power plants, an activity which will inevitably grow in the future.

## Nuclear energy and society

Generally speaking, if nuclear energy is to have a future, it will be essential to improve public participation in the related decision making. Lack of public acceptance has indeed put a stop to the industry in certain countries.




In many OECD countries, the public is concerned about the risk of nuclear energy, and this concern has to be clearly addressed. But it also needs to be put in perspective. Nuclear energy is now a mature technology and has proven in OECD countries to be very safe in practice. Serious accidents inflicting any sort of bodily harm are considerably few and far between, and overall less harmful than those that have been brought on by many other energy sources.

The nuclear industry works very hard to protect the public and workers in the industry. In addition to adhering to strict regulations in place, it has also sought, with considerable success, to limit occupational exposures. Over the past decade, occupational exposures have been almost halved, and are running at levels well below those required to protect worker health.

In terms of sustainable development and contributing to human capital, nuclear energy is an energy whose main resource is technology, and therefore it requires very highly qualified manpower. This contributes significantly to human capital. The institutional framework established, especially because of the need to control the risk to society, is practically unique, and also constitutes an important contribution to the social dimension. The institutional framework includes domestic regulatory regimes and international regimes such as the Non-Proliferation Treaty, which has been very effective in avoiding the proliferation of nuclear weapons.

OECD countries are also investigating research and education policies that would help ensure the necessary framework conditions for nuclear energy to contribute to sustainable development. Fostering the development of new technologies is also important, and I think that OECD/NEA participation in Generation IV will be helpful in successfully advancing towards these new, sustainable technologies.

In conclusion, the assessment of nuclear energy regarding the three dimensions of sustainable development - economic, environmental and social - must be done first on its own merits, but also in comparison with other energy sources, mainly fossil fuels and renewables. The OECD, with and through the contribution of the IEA and the NEA, can help governments in analysing criteria and trade-offs between these different energy sources. In this way, the OECD is well-positioned to help Member countries in establishing sustainable development policies. Yet it is important that we view sustainable development in relative terms, and not absolute ones. We have a duty to the world's population to promote sustainable policies that can realistically be implemented.

## Further reading

Nuclear Energy in a Sustainable Development Perspective (NEA, 2000), is available free of charge at www.nea.fr.

# Globe 2002

## - nuclear part of large environment meeting

For the first time in the series of the *Globe* environment and business conferences, nuclear energy was part of the **Globe 2002** conference and exhibition held in Vancouver, March 13 - 15 , 2002.

Atomic Energy of Canada Limited decided to join the many corporate sponsors of *Globe 2002,* which included The Globe and Mail, Export Development Canada, Ontario Power Generation, Shell International, several other energy and consulting companies and a number of federal and provincial departments and agencies. AECL had a stand in the exhibition and organized a session on *"Renaissance of Reactors: Nuclear Revival". (See sidebar.)*

*Seen at the opening plenary session of Globe 2002 are (L to R): federal Environment Minister David Anderson, Sir Mark Moody-Stuart, Maurice Strong.*

This seventh version of the Globe series drew over 3,000 delegates from 65 countries and its companion trade fair and exhibition was visited by thousands more.

The Globe conferences have the theme of "business and the environment" and have been aimed at promoting the concept that "doing good [for the environment] is good business". Globe 2002 was organized with three broad "tracks" or themes: corporate sustainability; environment and energy; international opportunities.

Despite the business emphasis, most of the plenary talks focussed on broader and political issues, such as the upcoming *"World Summit on Sustainable Development"* to be held in Johannesburg later this year, the ratification of the Kyoto Accord, and economic disparity.

**Maurice Strong,** former head of the UN Environmental Program, chaired the opening plenary session and first raised the reference to Johannesburg. Countries have not demonstrated the political will to make the necessary fundamental change in course, he asserted in his relatively brief opening remarks.

Federal Environment Minister **David Anderson** set the tone in his opening address. In his wide-ranging talk he noted that only 26% of large businesses produced an environmental report on their activities. "Business needs to understand the benefits", he stated. While disappointed that the USA withdrew from the Kyoto accord, he welcomed that country's "re-engagement" in the climate change debate. He was particularly critical of recent reports in the media from certain "lobby" groups claiming large costs if Canada ratified the Kyoto Protocol. They were using out-of-date data and making extreme and unrealistic assumptions, he claimed. "The environment has been degraded", he said in closing, "and business as usual is not an option". *(See the accompanying excerpts of Anderson's address.)*

Anderson was followed by **Sir Mark Moody-Stuart,** former chairman of the Royal Dutch/Shell Group of Companies and currently chairman of the Business Action Network for Sustainable Development. "There is", he began, "one overarching issue - how to develop sustainably." "Not just economic development", he continued, "but development which respects the environment and which delivers social benefits." There are two big challenges, he said, how to deliver the energy needed for development, and, how to develop the necessary governance structures.

"We can decouple energy from economic growth", he stated, " the link is broken at $25,000 p.a. per capita GDP". But, he noted there are two billion people with no access to modern sources of energy. Referencing the Third Assessment report of the Intergovernmental Panel on Climate Change, he predicted that the level of carbon dioxide in the atmosphere could be limited to 550 ppm, which, he suggested, could be tolerated. But even to hold at that level will require major changes in our use of energy.

"If we are to address the issues of energy for development and climate change we will need [appropriate] regulatory frameworks", Moody-Stuart said in closing. "Good governance at the local and national level is just as important as at the international level", he added. "The world is not short of financial and technical resources but [is] desperately short of community structures."

*Minister of Natural Resources Canada, Herb Dhaliwal, is seen at left with the moderator of the second plenary session at Globe 2002, Michael Phelps of Westcoast Energy, and Elizabeth Lowry, V.P. General Motors*

The plenary session on the second day focussed on "continental energy markets" with **Herb Dhawliwal,** recently appointed Minister of Natural Resources Canada, giving the first presentation. "About half of all the energy we produce is exported to the U.S.", he noted, and "we have real and legitimate concerns about our approaches to cutting greenhouse gases". Referring to the question of Canada ratifying the Kyoto Protocol the minister said, "we will only take a decision once we have a workable plan and full consultations have been completed".


*A view of the booth of Atomic Energy of Canada Limited at Globe 2002 with AECL's Tabitha Poehnell (far left) and Peter Allen (2nd from right) talking to visitors*

"Sustainable mobility", was the theme of the other speaker at the second plenary session, **Elizabeth Lowry,** vice-president, environment and energy, General Motors. While mentioning "eco-efficiency" in the use of chemicals, land and the reduction of emissions, she spoke primarily about the future of the automobile based on hydrogen. There are three major challenges that still need to be overcome, she stated, on-board storage, production (of hydrogen) and the infrastructure for distribution.

In the closing plenary session on the third day, UK deputy prime minister **John Prescott** focussed on "global inequality", the gap between rich and poor. Globalization can be good, he claimed, but it must be managed properly, noting that although there had been many gains in recent years there are still more than a billion people who are illiterate and without water.

The final speaker was **Klaus Toepfer,** secretary general of the United Nations Environment Program based in Nairobi, where, he said, the reality of poverty is very evident. Access to water and energy is key, he commented and noted that 1/6 of the world's population consume more than half of all of the energy used.

The large trade fair and exhibition filled most of the Vancouver Convention and Exhibition Centre located on the edge of the north channel. Designed to resemble the sails of a boat this striking building has become a landmark of that city. Many of the exhibits were from government organizations, with a large "pavilion" by the Government of Canada and somewhat smaller ones from: Alberta, Atlantic Canada, Austria, British Columbia, Ontario, United Kingdom, and United States. Many companies involved in environmental business were also on hand, including three exhibits of "environmentally-friendly" cars, electric, fuel cell, and natural gas powered.

Industry Minister Allen Rock chose the venue of the fair to announce an additional $20 million for NRC's Institute for Innovation located at the University of British Columbia to expand research on fuel cells and on sources of hydrogen.

Although nuclear power was not high on the agenda of this conference several of the plenary and other speakers alluded to it and the AECL booth appeared to be quite popular. There was only one openly critical comment about nuclear and that was from a woman who identified herself as a long-time B.C. environmentalist

Judging from the attendance and participation at Globe 2002, the theme of the series, environment and business, has become very popular. With the likely ratification of the Kyoto Protocol by many countries and the growing awareness of the need to move towards more "sustainable" and equitable development, Globe 2004 should be even larger.

# Nuclear Renaissance

## - the nuclear session at Globe 2002

Among the several special sessions at the Globe 2002 Conference there was, for the first time, one on nuclear power. It was titled *"Renaissance of Reactors: Nuclear Revival".*

Organized by Atomic Energy of Canada Limited, the session had four papers:

- *Environmental Stewardship and Clean Air: A New Look at the Role of CANDU Reactors*
  — presented by **Dave Torgerson,** senior vice-president, AECL
- *Nuclear Power - Sustainable, Long-term Solutions for the Future. The European Point of View*
  — by **Agneta Rising,** chairman, World Nuclear Association
- *Nuclear Renaissance: the Romanian Experience*
  — by **Lucian Biro,** president, National Commission for Nuclear Activities Control, Ministry of Waters and Environmental Protection, Romania
- *The Future of Nuclear Power in the U.S. Energy Policy*
  — by **Jan Freeman,** vice-president, Exelon Generation

Torgerson gave a wide-ranging talk on how nuclear power could benefit the environment. The increasing amount of carbon dioxide (CO2) being put into the earth's atmosphere, he said, pointed to the need and opportunity for new nuclear technology to combat the threat of climate change. Similarly, nuclear power plants would avoid the large emissions of sulphur oxide (SO2) and nitrous oxides (NOx) from fossil fuelled plants, which cause air pollution and acid rain.

Two potential applications of nuclear power that cold have significant benefits in reducing greenhouse gases, Torgerson noted, are the production of hydrogen through electrolysis and the use of CANDU generated steam to extract oil from the Athabaska tar sands. One 600 MWe CANDU reactor could produce enough hydrogen to supply 575,000 fuel cell powered cars without any CO2 . He went on to describe the CANDU NG and developments in waste management. "Nuclear energy is an important part of the overall energy mix", he stated in closing, "producing both environmental and economic benefits.

Rising argued that the health and environmental impact from various energy sources should be assessed in a systematic and scientific way. Nuclear, she said, is the only energy source that can meet a large-scale need for energy and at the same time meet ambitious environmental and health standards. She showed the results of a recent study by the European Union of deaths (acute and late) per TWh; ranging from 35 for oil, 25 for coal to 1 for nuclear.

Biro reviewed the history of nuclear development in Romania. The Cernavoda 1 unit is operating very well and producing about 11% of the country's electricity. Although work has begun on Cernavoda 2 and is planned for Cernavoda 3 he noted that coal and gas fired plants offer lower short term costs. He closed with a brief description of the role of his regulatory agency.

Freeman began with an overview of her company, Exelon Corporation, which has 50,000 MW of generation in operation or under construction, including 17 nuclear units that comprise 20% of the US nuclear capacity. There is an ongoing consolidation of the ownership of nuclear plants, she noted, going from over 50 operators in 1989 to 21 in 2001. Without adding any new plants the output of nuclear power plants had increased from about 550 TWh to 750 TWh over the last decade, equivalent, she said, to 22 plants of 1,000 MW each. US nuclear plants avoid 5 million tons of $SO_2$, 2.4 million tons of $NO_x$ and 164 million tons of $CO_2$ annually, she stated. Public opinion in the USA has become quite favourable to nuclear, she claimed. Freeman closed with a brief look at the pebble bed modular reactor concept that her company is pursuing along with others.

Unfortunately, this nuclear session attracted the smallest crowd of any of the special sessions at Globe 2002, suggesting that most attendees are not yet ready to accept nuclear power as part of the energy mix.

# Canada and climate change

## — excerpts from the address by David Anderson, Minister of the Environment, to the opening plenary session of the Globe 2002 conference

There has never been a more timely opportunity for GLOBE. In less than five months people from around the world, including as many as 150 world leaders, will gather in Johannesburg for the *World Summit on Sustainable Development.*

When I addressed this conference two years ago, I offered some ideas on how we could engage more players in moving forward with sustainable development. These ideas were organized with what I called " a new architecture of environmental management". This new architecture is composed of a range of principles whose intent is to channel market forces toward an economically strong and environmentally and socially sustainable Canadian society.

Over the past two years Environment Canada has been working to integrate the architecture into every aspect of how we address Canada's environmental priorities. Knowledge, innovative policy tools and partnerships have been at the top of our agenda.

I want to focus on the significant challenge that lies before us with respect to achieving our climate change goals and demonstrating the new architecture is already working to move us - both as government and as industry - in the right direction.

While my focus today is on climate change, it is important that we do not lose sight of our other key environmental priorities: reducing toxic substances in our environment; cleaning our air; and managing our forests.

The traditional environmental approach - where government sets the targets, makes the rules, and points the way - won't get us there. We need to focus on prevention rather than clean-up.

Business needs to better understand the economic benefits of sustainability, and, they must have the capacity to not only act on that understanding but also to measure their progress. A survey showed that only 26% of our largest companies produced environmental or sustainability reports.

Everyone has heard of the recent debates about the Kyoto Protocol. Some say we are proceeding too fast. Others suggest we are going too slow. Both sides are wrong. Considering that negotiations in Marrakech on the details of implementation concluded only four months ago I would argue that we are working on a reasonable timetable. And, despite reports to the contrary, we are developing a plan to achieve our Kyoto target. It is not a final plan - it cannot be at this stage. But, it will provide a good framework for discussion over the next months. We want to consult and adapt it to the views of provinces, industries, stakeholders, as well as average Canadians.

For Canada, domestic emissions trading (DET) is an innovative policy tool that will be key to meeting our climate change challenge. A Canadian system harmonized with the proposed international emissions trading program, not to mention a possible U.S. program, will ensure that a future DET works.

It is actually the international price of carbon credits that will determine what emission reductions might be most cost-effective. In essence, if we leave everything up to the market, the international carbon price will determine the balance between domestic reductions and the international purchase of credits.

The second part of our approach involves targeted measures to address emission in sector not covered by the domestic emissions trading system, such as residential and commercial buildings, transportation, forestry and agriculture.

Finally, the third part is government investments in any international credits that might be needed to close any remaining gap. At Marrakech we negotiated international rules that allow us to purchase emission reduction credits in the international market place and to incest in emission reduction projects in developing and developed countries.

On February 14, President Bush announced the U.S. climate change strategy that links the reduction of greenhouse gases to economic output. While I am not entirely satisfied with their approach it does put some important building blocks in place.

The most significant aspect is what the U.S. is doing with its investments in technology and science. We need to make comparable and compatible investments kin developing our knowledge. We must understand the cost of doing nothing.

We should not be put off by the worst-case Kyoto scenarios that have recently been in the media. Some lobby groups have produced cost estimates using out-of-date data that are unrealistic and presume that Canada is the only country ratifying the Kyoto Protocol. Within the next couple of months we expect to have an accurate picture of the range of possible costs.

In September, world leaders will meet in Johannesburg at the *World Summit on Sustainable Development* or Earth Summit 2002. The 1992 Earth Summit in Rio brought the challenges into focus, especially climate change. Earth Summit 2002 is a critical milestone in confirming a path towards a better world for everyone.

# Fabrication, Quality Assurance & Performance of PHWR Fuel in India

*by C. Ganguly*[1]

***Ed. Note:** The following paper was presented at the CNS sponsored 7th International CANDU Fuel Conference, September 2001. It had been intended to be included with the report on that conference in the last issue of the CNS Bulletin but its receipt was, unfortunately, delayed past the publication date.*

## Abstract

Pressurised Heavy Water Reactor (PHWR) is the backbone of the indigenous nuclear power programme in India. The Nuclear Fuel Complex (NFC) at Hyderabad is responsible for manufacturing zircaloy 4 clad natural uranium oxide fuel for the PHWRs in India, using magnesium-di-uranate concentrate from Uranium Corporation of India Limited (UCIL) and zircon sand from Indian Rare Earths Limited (IREL) as starting material. In the last two consecutive financial years (April-March), 1999-2000 and 2000-2001, the annual production of PHWR 220 fuel bundles at NFC exceeded 26,000 and the fuel for the initial cores of Kaiga 1&2 and RAPS 3&4 were delivered. In September 2000, NFC crossed a major milestone with the manufacturing of the 200,000th fuel bundle. NFC received the ISO-9002 certificate for quality management system from M/s. TUV, India in December 2000. The uninterrupted and timely supply and high quality of fuel from NFC for the 12 operating 12 PHWR units paved the way for the Nuclear Power Corporation of India Limited (NPCIL) to achieve more than 80% average plant load factor (PLF) in 1999-2000 and 2000-2001, keeping the I-131 activity in coolant channels way below the permissible limits. Several modifications in the fuel fabrication flowsheet, equipment and process parameters and quality control steps have led to significant reduction of radioactive aerosol, increase in productivity, minimisation of rejects and improvement in fuel quality.

## 1.0 Introduction

Out of the six nuclear power reactors that went into commercial operation all over the world in the year 2000, four are Pressurised Heavy Water Reactors (PHWRs), popularly known as CANDU, which are located in India. These reactors, namely, Kaiga 2, RAPS 3, Kaiga 1 and RAPS 4 are of the PHWR 220 type and were connected to the grid in March, June, October and December 2000 respectively. Presently, there are 12 operating PHWRs in India with a total installed capacity of 2400 MWe as shown in Table 1.

The construction activities of two PHWR 500 units at Tarapur (TAPP 3&4) are progressing rapidly. These are the fore runners in the series of PHWR 500 MWe units, which would be constructed in India in the coming years. Excavation work of two more PHWR 220 units has started at Kaiga (Kaiga 3&4) in March 2001. NPCIL is planning to construct four PHWR 500 units at Rajasthan (RAPP 5-8) and two additional PHWR 220 units at Kaiga (Kaiga 5&6). By the year 2020, sixteen PHWR 220 and twelve PHWR 500 units are likely to be operational in India with a total installed capacity of 9280 MWe.

Figure 1 shows the map of India, indicating the locations of the activities in the front-end of the PHWR fuel cycle. Presently, the Uranium Corporation of India Limited (UCIL) is operating three underground mines at Jaduguda, Narwapahar and Bhatin in the Singhbhum District of Jharkhand State and preparations are underway to open a fourth mine at Turamdih in Singhbhum. In the uranium concentration plant of UCIL at Jaduguda, the ores are crushed, milled and subjected to sulphuric acid leaching followed by purification by the ion-exchange process and precipitation of uranium concentrate in the form of magnesium di-uranate (MDU), popularly known as yellow cake, which contains around 70% $U_3O_8$. Apart from Singhbhum District, the Atomic Minerals Directorate of Exploration and Research (AMD) have confirmed uranium deposits of nearly 13,000 tons (of $U_3O_8$) in the Cretaceous sedimentary basin at Meghalaya State and in the last two years significant uranium intercepts have been met in the Proterozoic basins at Cuddapah and Bhima in Andhra Pradesh and Karnataka States respectively (1). In addition, uranium deposits have also been discovered in Albitite zones at Aravallis in Rajasthan State. Techno-commercial feasibility and environmental studies are underway as part of the pre-mining activities in these locations.

India has abundant reserves of zircon in the beach sands

1 Dr. Ganguly is Chief Executive of the Nuclear Fuel Complex, Department of Atomic Energy, Hyderabad, India

of the coastal States of Kerala, Tamil Nadu and Orissa, which are exploited by the Indian Rare Earths Limited (IREL). Nuclear Fuel Complex (NFC) at Hyderabad is responsible for manufacturing zircaloy clad natural uranium oxide fuel bundles for PHWRs, using magnesium di-uranate from UCIL and zircon sand from the IREL plants at Chavara and Manavalakurichi as starting materials.

## 2.0 Fuel Fabrication

The manufacturing of PHWR 220 fuel bundles at NFC is carried out at Uranium Oxide Plant (UOP), Ceramic Fuel Fabrication Plant (CFFP), New Uranium Oxide Fabrication Plant (NUOFP) and New Uranium Fuel Assembly Plant (NUFAP). UOP and CFFP are in operation since the inception of NFC in the early 1970s. The NUOFP and NUFAP went into commercial operation in 1999.

The fabrication processes followed at NFC for manufacturing zircaloy hardwares, $UO_2$ pellets and PHWR fuel bundles have been described in details in the proceedings of the 6th International Conference on CANDU Fuel (2). Figure 2 summarises the major process steps followed at NFC for production of PHWR fuel bundles. At UOP and NUOFP, the yellow cake (Magnesium di-uranate - MDU) received from UCIL or uranium oxide scrap in the form of rejected sintered pellets, green pellets and sludges from centerless grinding units are dissolved in nitric acid followed by purification by solvent extraction and precipitation by ammonia to obtain pure ammonium di-uranate (ADU). The ADU is subjected to controlled calcination, reduction and stabilisation to obtain sinterable grade $UO_2$ powder of desirable specific surface area, particle size and oxygen to metal ratio.

At CFFP and NUOFP, the $UO_2$ powder is converted to free-flowing granules by either precompaction-granulation or roll compaction-granulation and compacted to green pellets in double acting hydraulic presses utilising multiple die punch sets. The pellets are loaded in molybdenum charge carriers and sintered in pusher type continuous sintering furnaces at around 1700°C in cracked ammonia. The sintered pellets are ground and inspected in terms of dimension, density and visual defects. The accepted pellets are stacked and loaded into thin walled zircaloy 4 (Zr-4) cladding tubes. At CFFP and NUFAP, the cladding tubes containing the pellets are hermetically sealed with end plugs using resistance welding technique. Next, zircaloy 4 spacer and bearing pads are resistance welded on the fuel pins and finally 19 such fuel pins with appendages are clustered to form a fuel bundle for PHWR 220 MWe unit. However, recently a few hundred fuel bundles have been manufactured by employing an improved technique (3) in which bearing and spacer pad appendages are resistance-welded on zircaloy 4 cladding tubes prior to $UO_2$ pellet loading.

Figure 3 shows the annual production of PHWR fuel at NFC during the last five years. In the last two consecutive financial years (April-March), 1999-2000 and 2000-2001, the annual production of PHWR 220 fuel bundles at NFC exceeded 26,000 and the fuel for the initial cores of Kaiga 1&2 and RAPS 3&4 were delivered. The cumulative production of PHWR 220 fuel bundles at NFC, since its inception in the early 1970s, crossed the 200,000th mark in September 2000. Each 19-element PHWR fuel bundle contains around 15 kg uranium oxide and generates 650,000 units (kWh) of electricity.

During the last 2 years, great emphasis has been given to radiological safety, improvement in fuel quality, minimisation of rejects and recycling of uranium oxide scrap. The major modifications in the plant and process flowsheet include:

i) containment of equipment and improvement in the ventilation system in the $UO_2$ powder area,
ii) adapting simple and effective technique for large scale recycling of green and sintered $UO_2$ scrap
iii) introduction of a spray drier unit in NUOFP for obtaining nearly free-flowing ADU powder,

| Plant | Capacity | Date of Commercial Operation |
|---|---|---|
| Rajasthan Atomic Power Station (RAPS), Rawatbhatta | | |
| RAPS-1 | 100 MWe | 16th December 1973 |
| RAPS-2 | 200 MWe | 1st April 1981 |
| RAPS-3 | 220 MWe | 1st June 2000 |
| RAPS-4 | 220 MWe | 23rd December 2000 |
| Madras Atomic Power Station (MAPS) Kalpakkam | | |
| MAPS-1 | 170 MWe | 27th January 1984 |
| MAPS-2 | 170 MWe | 21st March 1986 |
| Narora Atomic Power Station (NAPS) | | |
| NAPS-1 | 220 MWe | 1st January 1991 |
| NAPS-2 | 220 MWe | 1st July 1992 |
| Kakrapara Atomic Power Station (KAPS) | | |
| KAPS-1 | 220 MWe | 6th May 1993 |
| KAPS-2 | 220 MWe | 1st September 1995 |
| Kaiga Atomic Power Station | | |
| Kaiga-1 | 220 MWe | 16th November 2000 |
| Kaiga-2 | 220 MWe | 16th March 2000 |
| **Total 240 Mwe** | | |

*Table 1: Operating Pressurized Heavy Water Reactors in India*

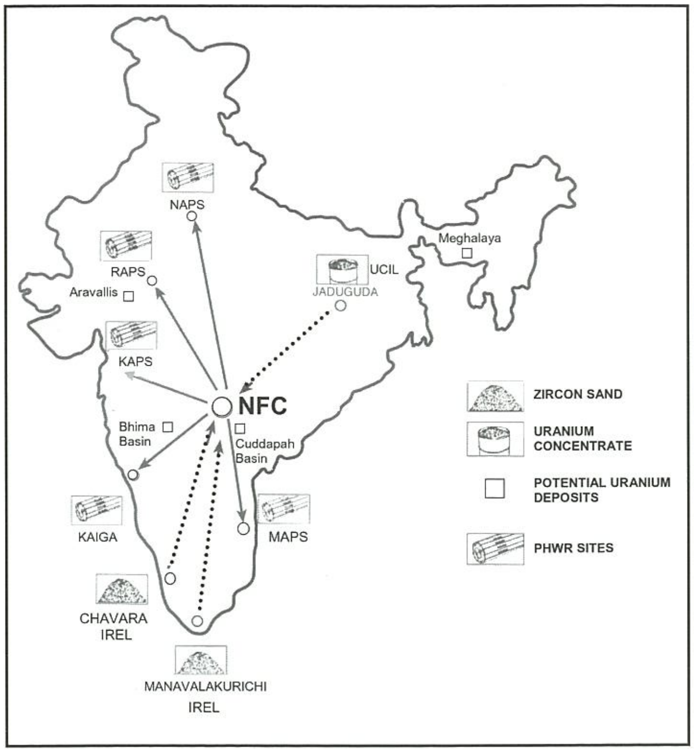



*Figure 1: PHWR Fuel Cycle Activities in India*

iv) introduction of roll compaction-granulation process for improved productivity of free-flowing $UO_2$ granules and admixing solid lubricant to $UO_2$ granules,

v) change over to tungsten carbide dies and cryogenic-treated die steel punches for $UO_2$ pellet compaction,

vi) switching over to chamfered pellets and

vii) optimisation of $UO_2$ pellet loading in molybdenum charge carriers and sintering cycle

All these factors yielded very rich dividends by way of higher productivity, lower specific energy consumption, enhanced grinding recovery and minimum down time of equipment, which led to significant reduction in fuel fabrication cost.

The 19-element fuel bundles manufactured by the modified route, utilising zircaloy 4 tubes with spacer and bearing pad appendages welded prior to pellet loading and encapsulation, were introduced on a trial basis in Madras Atomic Power Station (MAPS) and Kakrapar Atomic Power Station (KAPS), where their performance has been satisfactory.

## 3.0 Quality Assurance

There has been a continuous effort to improve the quality of fuel. In December 2000, NFC received the ISO-9002 Certificate from M/s. TUV, India based on the quality management system.

Close interaction of fuel fabrication and quality assurance teams resulted in improved efficiency in all the plants. In the uranium oxide powder production plants, it was possible to achieve significant improvement in the quality of $UO_2$ powder in terms of optimum specific surface area, particle size and oxygen to uranium ratio. As a result, the percentage acceptability of the $UO_2$ powder batches, based on sinterability test, reached impressive figures of 97.17% and 99.49% in 1999-2000 and 2000-2001 respectively. It was also possible to bring down the average hydrogen content in sintered pellets in the range of 0.15 to 0.16 ppm and average hydrogen in graphite coated zircaloy 4 tubes less than 18 ppm.

For quality assurance of fuel elements and assemblies, new techniques were introduced for better reliability and repeatability. One such step is the introduction of dimension measurement system based on image analysis technique for evaluating fuel tubes, end plugs and spacer and bearing pads. It was possible to minimise significantly the rejections due to weld defects by employing a novel ultrasonic testing (UT) technique (4) of welds as a non-destructive process control tool, using a point focussed spherical

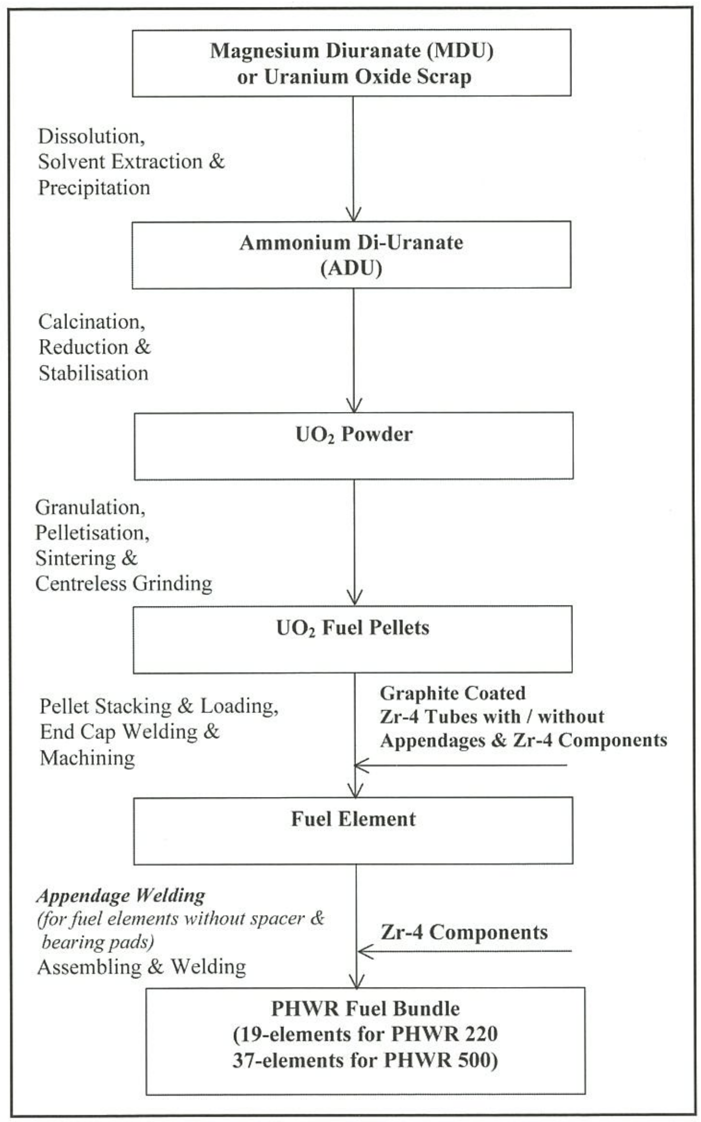



*Figure 2: Flowsheet for Manufacturing PHWR Fuel Bundles at NFC*

probe of 30 MHz. The UT signals could be easily resolved and specific weld defects like non-fusion line, weld spark, sheath folding, etc. and their locations could be identified quickly, without the need for machining the weld up-set. The method utilises an incident beam at an angle of 27°, focussed at weld up-set (outside) as a reference point. Thus, the dependence on destructive metallography for evaluation of process and set-up welds is eliminated. The rejection level of fuel elements due to welding defects, based on the results of the helium leak testing, could be kept as low as 0.003%.

## 4.0 Performance

The uninterrupted and timely supply and high quality of fuel from NFC paved the way for the Nuclear Power Corporation of India Limited (NPCIL) to operate the 12 PHWR units with an average plant load factor of 80% during the last two years. Thus, NPCIL could generate 10,300 million units and 14,300 million units (kWh) of electricity during 1999-2000 and 2000-2001 respectively. These are the highest figures of NPCIL since its inception and accounted for nearly 3% of the total annual electricity produced in India. The average I-131 activity, a measure of fuel behaviour in the reactors, has been reasonably low (less than 5 micro curie per litre). The average discharge burn-up of fuel in the past two years was in the range of 7,000 MWd/t, which is higher than the average design burn-up of 6,700 MWd/t.

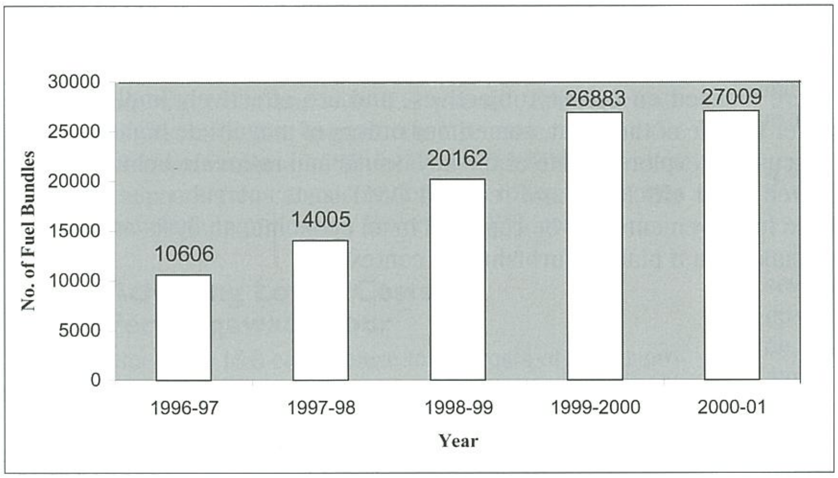



*Figure 3: Production of Zircaloy 4 Clad 19-Element PHWR Fuel Bundles at NFC*

## 5.0 Looking Forward

- The three decades of experience in industrial scale manufacturing of 19-element PHWR 220 fuel bundles, utilising indigenous resources of uranium and zirconium, has instilled enough confidence to set-up a state-of-the-art facility at NFC utilising indigenous equipment for manufacturing 37-element fuel bundles for the forthcoming PHWR 500 units. The main objective is to manufacture high quality fuel economically, while ensuring high radiological safety standards.
- The recent trend in PHWR fuel development all over the world has been to enhance the average burn-up by a factor of 2 to 3 from the present level of 6,700 MWd/t. For this, efforts are underway to introduce advanced fuels like slightly enriched uranium (SEU) or recycled uranium (REU) oxide, $(U,Pu)O_2$, $(Th,Pu)O_2$ and $(Th,U^{233})O_2$ containing 1 to 2% 'fissile' material. For this, there is a need to develop a suitable, dust-free advanced process, amenable to automisation and remotisation, for manufacturing high-density oxide or mixed oxide fuel pellets in order to minimise radioactive aerosol and exposure of plant personnel to radiation.
- High radiological safety, development of cost effective processes in nuclear fuel cycle, "secured automated fuel fabrication" routes, methods for real time accounting of nuclear materials, a 6 sigma quality culture in fuel production and achieving nearly zero fuel failure in reactors are some of the major objectives of PHWR fuel technology in India in coming years.

## Acknowledgement

The author would like to thank his colleagues at AMD, NPCIL and NFC, in particular Mr. R.N. Jayaraj, Deputy General Manager, Natural Uranium Fuels Group, NFC, for providing necessary inputs for preparation of this paper. The author is grateful to the International Atomic Energy Agency (IAEA) for financial assistance and Chairman, Atomic Energy Commission, Government of India for nominating him to present the Country Paper in the 7th International CANDU Fuel Conference at Kingston, Canada.

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# Control System Upgrades Support Better Plant Economics

*by J. de Grosbois, A. Hepburn, H. Storey, and R. Basso*[1], *V. Kumar*[2]

***Ed. Note:*** *This is the second paper in a series on CANDU plant control system upgrade issues. The first paper was published in Vol. 23, No. 1, January 2002.*

## Abstract

This paper (second in the series, see [1]) provides insight on how nuclear plants can achieve better efficiencies and reduced operations and maintenance (O&M) costs through focused control system upgrades. An understanding of this relationship is necessary to properly assess the economics of plant refurbishment decisions. Traditional economic feasibility assessment methods such as benefit cost analysis (BCA), internal rate of return (IRR), benefit cost ratios (B/C), or payback analysis are often performed without full consideration of project alternatives, quantified benefits, and life cycle costing. Consideration must be given to not only capital cost and project risk, but also to the potential economic benefits of new technology and added functionality offered by plant upgrades.

Recent experience shows that if upgrades are focused on priority objectives, and are effectively implemented, they can deliver significant payback over the life of the plant, sometimes orders of magnitude higher than their initial capital cost. The following discussion explores some of the key issues and rationale behind upgrade decisions and their impact on improved plant efficiency and reduced O&M costs. A subsequent paper will explain how the justification for these improvements can be captured in an economic analysis and feasibility study to support strategic decision-making in a plant refurbishment context.

## Achieving Improved Plant Efficiency

A recent study of U.S. nuclear plants [2] presents a compelling argument. To be competitive in a de-regulated electricity generation market, nuclear power plants must maximize the number of megawatt hours (MWh) generated to cover fixed costs while minimizing the cost per MWh to cover variable costs. This is accomplished by maximizing the ***capacity factor*** and minimizing ***total cost.*** These two primary performance indicators (output and cost) are functionally related to several secondary performance indicators. These secondary performance indicators are common industry terms used to calculate plant efficiency. It is useful to understand how these performance indicators are a factor in the economics of refurbishment decisions, and in specifically how instrumentation and control (I&C) upgrades can improve them. The most common overall measure of plant efficiency is "cost per MWh", and it is expressed as the ratio:

$$\text{Cost per MWh} = \text{Total Costs} / \text{Actual Output}$$

This ratio can be expressed in terms of secondary performance indicators as:

$$\frac{\text{O\&M Costs} + \text{Fuel Costs} + \text{Capital Costs}}{\text{Capacity Utilization} \times \text{Scheduled Availability} \times \text{Reliability Factor} \times \text{Max. Rated Capacity}}$$

Where these secondary performance indicators are defined [2] as:

- *Capital Costs* are any plant or equipment costs that must be capitalized.
- *Capacity Utilization* is the capacity factor while the plant is operating and is *(1 - Production Loss Rate)*
- *Scheduled Availability* is *(1 - Scheduled Outage Rate)*
- *Reliability Factor* is *(1- Forced Outage Rate)*
- *Maximum Rated Capacity* is the annual capacity that could be produced if the station were operated continuously at its licensed power limits.

To maximize output, the plant operator must either:

- increase *Capacity Utilization* by operating the plant closer to its licensed *Maximum Rated Capacity* limits,
- increase the *Scheduled Availability* by minimizing the *Scheduled Outage Rate* (i.e., by reducing maintenance outage time), or
- increase the *Reliability Factor* by minimizing the *Forced Outage Rate* [2].

During the last 10 years, U.S. nuclear power plants have increased the median industry capacity factor from 68 % in 1989 to 88 % in 1998 [2]. This was achieved by:

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2 Sprott School of Business, Carleton University, Ottawa Ontario

- reducing the median *Production Loss Rate* during operation from 5.9 % to 0.7 %,
- reducing the median *Scheduled Outage Rate* from 22.5 % to 10.3 %, and
- reducing the median *Forced Outage Rate* from 1.5 % to 0.5 % [2].

Other articles confirm these observations and provide analysis of recent turnaround performance of U.S. nuclear plants. Statistics (from 1995) on production-cost control for the ten top-ranking U.S. units indicate costs per MWh range from $12.88 US/MWh at Virginia Power's North Anna Station to $15.48 US/MWh at Marine Yankee Atomic Power's Marine Yankee Station [3]. Overall, the U.S. industry has seen a marked reduction in plant production costs over the past decade.

Understanding how I&C upgrades can have direct effect on these performance indicators provides a strong argument for improved control and monitoring systems in domestic CANDU3 plants. While the refurbishment of some domestic CANDU stations is underway, most have not yet started, and collectively the aging domestic stations are far from achieving the admirable performance statistics of their US counterparts. However, it is reasonable to assume that post-refurbishment performance will be at par with U.S. plants. For refurbishment decisions, any I&C upgrade that promises to achieve competitive improvements in the total cost per MWh equation should be given serious consideration. The following section explores how I&C upgrades can lower the MWh cost.

## 2 Achieving Lower Costs Per Megawatt Hour

Improvements in I&C can achieve lower costs of power production in each of five areas:

- increased *Capacity Utilization* by reduced production losses (i.e. operate closer to the plant's Maximum Rated Capacity),
- reduced *Scheduled Outage Rate* (i.e. reduce the frequency of scheduled outages, or make them shorter in duration),
- reduced *Forced Outage Rate* (i.e. reduce the frequency of forced outage and the time needed to recover from them),
- reduced *O&M Costs* (i.e. reduce labour, maintenance costs, spare parts etc.), and
- increased *Maximum Rated Capacity* (i.e. increasing the design capacity and getting the regulator to approve an up-rating).

The following sections describe how these improvements in the underlying performance indicators can be achieved to lower the overall cost per MWh equation.

### 2.1 Increased Capacity Utilization and Rated Capacity

I&C improvements can increase *Capacity Utilization* in several areas, such as in safety system calibration, and in control system tuning. Improvements in the accuracy and confidence of set-points can result in small reductions in operating margin-to-trip that can have significant economic benefit to a station, particularly under conditions where the plant is de-rated due to age related conditions. Some CANDU stations have had to live with forced de-ratings, under certain conditions, due to known control system design deficiencies. Upgrades that would address these deficiencies could allow some trip set-point conservatisms to be relaxed, improving plant capacity utilization.

One means of increasing *Maximum Rated Capacity* would be to provide improved online core monitoring calculations. Certain changes to these calculations would require the installation of additional field instrumentation. With modern plant control and information systems, plant models previously run only offline could easily be run online. Improvements could be considered such as more accurate reactor power distribution calculations computed essentially in real-time. The resulting increased performance would allow better recovery of operating margin (in some circumstances), better avoidance of poison-out, and better overall fuel burn-up rates. The economics of even small gains in these areas, in the order of 0.5% improvement, would have meaningful payback over the extended life of a refurbished plant. Many refurbished US nuclear stations have implemented I&C upgrades that (among other improvements) have supported successful license approvals for up-ratings to increase Maximum Rated Capacity. CANDU plants have yet to explore this avenue in detail.

### 2.2 Reduced Outages and Lower O&M Costs

The trip computer subsystems of the shutdown systems of several domestic CANDU plants will need to be replaced during up-coming refurbishments to ensure reliable performance for an extended plant life of 30 years or more. The addition of more advanced trip conditioning logic (known as "local coincidence" logic) as part of these upgrades would be another way to directly reduce forced outages. Analysis of data on completed trips at a domestic CANDU 6 unit that has no local coincidence logic in either SDS1 or SDS2 show that approximately 18% of all completed Shutdown System (SDS) trips from high power were not necessary and could have been prevented had local coincidence logic been implemented on both SDS1 and SDS24. This number rose to 27% when all completed trips at low power and under sub-critical conditions were taken into account. The outages that ensued from these trips contributed significantly to the unit's Forced Outage Unavailability.

Another direct factor in reducing the number of unnecessary outages is the control room operator's ability to deal with plant upsets. Studies done by the CANDU Owner's Group have shown that improvements to the central alarm annunciation system, and in particular alarm prioritization, filtering, and coalescing would result in significant improvements in operator response to upset conditions [4]. These studies found that such improvements would address many of the problems associated with current annunciation systems, resulting in a potential savings of over $2 million a year per unit in reduced unforced outages [4]. This is achieved by enabling more effective recovery form upsets and by helping to further eliminate unnecessary outages or power reductions. The duration of each outage could also be reduced with the implementation of automated plant start-up. It is estimated that control com-

3 Registered trademark of Atomic Energy of Canada Limited (AECL)

puter automation and sequencing of the start-up process could eliminate several hours from each outage.

Scheduled and Forced Outage Rates (i.e. by affecting both outage duration and frequency) and O&M costs can be reduced by taking advantage of improved instrumentation and monitoring. Better information can result in the ability to avoid and predict equipment failures, thus reducing outage time. Improved instrumentation and monitoring can be one of the primary drivers to achieving effective maintenance on large plant systems and equipment. Providing timely and more detailed system and equipment information to system responsible engineers allows root causes to be identified. Consequently, mitigation can be better targeted, and repeat failures avoided. Up-front investments in diagnostic and monitoring equipment, when combined with staff training, can directly improve maintenance program effectiveness and lower the costs of power production.

Predictive maintenance programs can add 8% to 12% savings to a traditional preventative maintenance program [5], primarily by avoiding unnecessary maintenance. Predictive maintenance program savings are usually in terms of avoided cost and therefore require historical failure data to reinforce a business case to justify monitoring equipment often needed to implement them. Aging CANDU plants being considered for refurbishment are prime candidates. Historical costs for various plant sub-systems can be determined and predicted savings could be based on projected maintenance cost reductions.

Proactive maintenance programs go one step further and can provide a more complete picture of plant health and provide predictive identification of problems to both operations and maintenance staff. This approach emphasizes immediate identification and resolution of off-normal conditions. Savings provided by proactive operations and maintenance programs are estimated to be 5% to 10% above predictive maintenance approach, including all the initial investment costs [5]. Further, in moving from a basic reactive maintenance mode to a proactive mode, it is common to find a total production life cycle cost savings on the order of from 25% to 40% [5].5 Most modern process plants (e.g. chemical) go beyond predictive maintenance and implement proactive maintenance programs. Proactive maintenance requires operations staff to be directly involved in the maintenance process. Asset management and upgrade decisions (which are often tied to outage planning) can then be based on known equipment degradation rates and more optimal decision methodology (i.e. considering risk and timing of replacement cost decisions). As a result, planned maintenance outages rather than forced outages (in response to an unexpected breakdown) become the norm.

The nuclear industry lags behind other industries in achieving the benefits of proactive maintenance for a number of reasons. In general nuclear plants are much older and more complex. The I&C upgrades and the operational changes required tend to be more difficult and costly, especially in the context of a regulated, and procedurally-driven and safety-oriented operating environment. Despite this, some CANDU plants have made considerable progress towards a proactive maintenance infrastructure with advances in online and continuous system health monitoring. For example, several have in-house developed "data gateways" to feed real-time plant process data from the plant control computer into Historical Data System (HDS) archives. These systems manage life-of-plant data archives, and in most cases also collect data from some of the many stand-alone data acquisition systems in the plant. Desktop client tools allow system responsible engineers to extract and display near real-time data or historical process data on their desktop computers over a local area network. Data mining opportunities exist with the data that is available in these HDS archives and can be used to reduce the need to do maintenance. For example, comparing the redundant pressure signals from the HDS archive could dramatically reduce the need to do pressure transmitter calibration work. It could be shown that the redundant signals all track each other within close tolerances.

Currently, most domestic CANDU stations have a mix of preventive, predictive, and proactive maintenance strategies. It is expected that with an eventual replacement of the aging plant process computers, the quantity and quality of system health data will improve. Better data and tools are expected to improve plant performance and reduce O&M costs further. A subsequent paper in this series will provide better insight into how these improvements can be factored into a financial justification for plant control computer replacement. The promise of savings on this magnitude warrants a closer look at the underlying I&C infrastructure and technology upgrades needed to support this approach.

## 3 Improvements with Integrated Plant Systems

Nuclear plants are moving toward more integrated plant-wide control and information systems, but progress is often slowed by difficulties interfacing with or replacing the diverse and complex range of existing legacy and stand-alone systems in most plants. A modern control system would offer many benefits in upgrading control and monitoring equipment on many of the older stand-alone systems including ease of integration, inter-communication, and modularity. Migration of older stand-alone systems to a single technology platform would offer maintenance cost reductions and enhanced capabilities. Common in newer plants, this approach has many benefits including integrated systems for plant control, plant display, historical data systems, system surveillance, and health monitoring.

Upgrades could be considered in two general groups: control system upgrades associated with the main control room,

4 Data from plant condition assessments done in 2001.

5 Note: this data is from a study [5] done at the Pacific Northwest National Laboratory (PNNL) and was to demonstrate that the savings are real, rather than simply optimistic projection. The study was based on a United States Marine Corps (USMC) thermal energy (heating and cooling) central energy plant. The project was designed to provide a proof of principle by giving a clear before and after measurement of the savings resulting from implementing a proactive O&M concept. The study was built around the implementation of a proactive approach and integrated an understanding of degradation mechanisms from the Nuclear Plant Aging Research Program (conducted by the U.S. Nuclear Regulatory Commission)

and non-control room system upgrades. Systems that could be incorporated into the first group include the following:

- Plant (Digital) Control Computers,
- Central Annunciation System,
- Panel-Mounted Displays,
- Fuel-Handling Control System,
- Contact Scanner Monitor,
- High Speed Data Loggers,
- Safety System Monitoring Computers/Systems,
- Electro-Hydraulic Governor Controls,
- Auxiliary Boiler Controls, and
- Post Accident Monitoring Systems.

Many of the stand-alone data acquisition and monitoring systems found in CANDU plants are not interconnected. Significant O&M costs savings could be achieved if they were implemented with common and standardized equipment. In addition, there are many hardwired device control systems that use relay logic or older analog controllers. These are also candidates for replacement. This would allow common parts, training, and maintenance procedures as well as improvements in O&M and system health monitoring. In the future, these systems, and others currently not being monitored could be integrated into a single plant-wide system.

Some of the non control room -related systems that in most CANDUs are already implemented with stand-alone monitoring or control systems and might be considered for integration in an upgrade include:

- Billing and Metering,
- Radiation Monitoring,
- Fault Recorders,
- Chemistry Monitoring,
- D2O Auxiliary Management Systems,
- Reactor Building Pressure Test Monitoring,
- Meteorological Monitoring,
- Gaseous Fission Products and Delayed Neutron Monitoring,
- Seismic Monitoring,
- Feeder Thinning Monitoring,
- Condensate Polisher Monitoring and Control,
- Ultra-Sonic Flow Measuring Systems,
- Leak Detection Monitoring,
- Cathodic/Galvanic Protection Monitoring, and
- Standby Generator Monitoring and Control.

## 4 Summary and Conclusions

Competition in a de-regulated electricity generation market will force nuclear power plant owners to continuously focus on maximizing output and minimizing total cost of production. Plant control system upgrades will be a key factor in meeting this challenge by offering improved plant efficiencies and reduced O&M costs. Better quality and more timely data coupled with improved plant-wide systems integration can support direct improvements to plant control, operations, and maintenance. These improvements can in turn have a direct impact on plant performance indicators that determine the MWh output and cost function. The significant long-term benefits to be realized by such upgrades provide a sound basis for their financial and economic justifications. Aging domestic CANDU plants facing refurbishment decisions should take a second look at the long-term payback of I&C upgrades. They are a key ingredient in achieving minimum cost per MWh, a prerequisite to competitiveness and profitability in the emerging deregulated market. To realize the benefits of new control system technology and plant-wide system integration, better financial and economic arguments are needed that recognize the benefits of performance improvements and cost-savings. The next paper in this series will explore methodologies for sound economic justification of plant control system upgrades.

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*Note the following correction to the previous (1st) article in this series [1]: The reference to British Nuclear should have been to British Energy. We apologize for the oversight.*

# Nuclear Education and Training in The Internet Age

*by George Bereznai*[1] *and William Garland*[2]

***Ed. Note:*** The following paper was first presented at the 22nd CNS Annual Conference, June 2001. The authors state that its message is still very relevant.

## Abstract

Student enrolment in nuclear engineering programs offered by Canadian universities has been declining, and at some universities has fallen below the minimum level needed to sustain the program. At the same time, a significant number of engineers working in the nuclear industry have retired and many more will be reaching retirement age in the next few years. The operation and maintenance of the 14 in-service CANDU units, the refurbishment of the four Pickering 'A' units and of the four Bruce 'A' units will require a significant level of new engineers and scientists. Service support for the CANDU units operating overseas, the construction of two units in China, the completion of Cernavoda 2, and the market for several more CANDU units in Asia, will also require significant numbers of new graduates.

The vast amount of information that the future practitioners of the nuclear power industry need to be aware of will be increasingly difficult to disseminate with the traditional classroom-based education and training methods. Almost all of the documents required for the design, analysis, procurement and operation of a nuclear unit are now generated by computer, and increasingly such information is accessible where and when needed via the company Intranet. The authors have developed an Internet/Intranet compatible self-paced interactive multimedia approach to deliver a course on CANDU Systems and Operations. The course has been offered at ten universities in six countries, including Thailand, China, Indonesia, Vietnam, the Philippines, as well as Canada.

## Introduction

Nuclear engineering is a highly specialized discipline. It is only offered at a few universities globally, and most of the programs are at the graduate level. With only a few nuclear power plants having been ordered in the last 20 years, the enrolment in nuclear power plant engineering in particular has decreased to such a low level that many university programs have been discontinued. However, demand for nuclear engineers will continue, and is expected to increase, as many of the practicing nuclear engineers are reaching retirement age, the operating power plants require more maintenance and upgrades, particularly as the economic and environmental benefits of extending the operating lives of these power plants becomes apparent, and as initiatives for plants with new technologies are pursued. The resultant mismatch between the supply and demand for the next generation of nuclear power plant engineers is only now being recognized, by both industry and the universities, as approaching crisis dimensions.

For Canada, the operation and maintenance of the 14 in-service CANDU units, the refurbishment of the four Pickering 'A' units and of the four Bruce 'A' units will require a significant level of new engineers and scientists. Service support for the CANDU units operating overseas, the construction of two units in China, the completion of Cernavoda 2, and the market for CANDU units in Asia, will also require significant numbers of new graduates.

Developing countries wanting to benefit from the use of nuclear power as part of their long-term energy mix, as demand for electricity increases with the increasing economic activity and improving living standards, face a unique problem. They have to develop a sufficient number of experts to staff the regulatory agencies, the research and development institutes, the utility departments and key industries needed to establish the infrastructure that will enable each country to make its own evaluation of the applicability of nuclear power.

Thailand faced such a scenario in the mid 1990s when the use of nuclear energy, to meet the rapidly increasing demand for electricity, was considered. Atomic Energy of Canada Limited (AECL) and the Canadian International Development Agency (CIDA) reached agreement with the Thai government, the Electricity Generating Authority of Thailand (EGAT), Chulalongkorn University, the Organization of Atomic Energy for Peace (OAEP) and several Canadian universities to conduct a Nuclear Human

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2 McMaster University, Hamilton, Ontario

Resources Development (HRD) Project [1]. The CIDA funded portion of the Project operated from 1995 to 1998, during which time 35 courses were developed and delivered by Canadian experts, and over 400 Thai engineers, scientists, educators and administrators participated in the program.

## Distance Learning

One of the key requirements of the Thai-Canadian HRD Project was to investigate how distance learning techniques could be used to deliver courses, and how the use of such technology could contribute to the long term sustainability of nuclear education and training in both Canada and Thailand. The use of video conferencing via satellites was initially considered, but the cost of equipment, communication charges and the 12 hour time difference between Thailand and Eastern Canada was shown to make this technology impractical. However, video taping of all lectures delivered in Thailand by the Canadian experts was considered to be useful in order to produce a permanent record of the lectures.

With a view to the expanding role of the Internet that was becoming evident in 1995, it was also decided to have all the course material produced in electronic form. This would, as a minimum, allow students and industry practitioners to access the course material in hard copy and electronic form, sustaining the program beyond the three years during which CIDA funded the travel of the Canadian lecturers to Thailand. Whether the materials were to be self-studied or courses were to be delivered by Thai lecturers, e-mail could be used to maintain fast and inexpensive communication between Thai and Canadian subject matter experts.

More recently the need for distance learning has become apparent beyond the original scope of the Thai HRD Project.

Considering the widely scattered locations of the existing CANDU plants in Canada, as well as the export markets that range from Europe, to Asia and South America, the need for education and training in CANDU technology is global. To meet this need, the use of learning technology that was not campus-based has become a strategically important component of supporting the use of CANDU power plants. Since the lecturers and other CANDU subject matter experts are also widely scattered and could not be relocated to any one campus, "distributed education" is the term that, in our opinion, best describes the type of learning environment that should be used to meet the industry's needs to develop, maintain and upgrade the knowledge of personnel in the nuclear industry.

## Interactive Multimedia

The rapid growth in using computers and the Internet in information processing and communication is well known. Since education and training are essentially about the sharing of knowledge, one would expect a similar growth and wide acceptance of IT by the learning institutions. Although there are an increasing number of courses and programs that may be studied via computers and the Internet, the vast majority of education and training world wide still takes place in the conventional classroom setting. Apart from the resistance to change by the tradition-bound educational institutions, the high cost of developing interactive course material has been used as the main reason for not embracing IT-based education. Production efforts of several hundred hours per one hour of finished lecture content have been quoted for good quality multimedia course material.

In order to minimize development costs, we needed to find a technique that made good use of the course material already developed for the Thai-Canadian HRD Project. Since the lectures were delivered with the help of overhead projectors, the authors decided to implement an IT-based learning system that retained as much of this format as practicable. Having obtained good educational results with the use of a power plant simulator running on a PC [2], a technique that simulated classroom course delivery was developed.

## Lecture Simulator

The typical classroom lecture is essentially a "show and tell" presentation: the lecturer displays the main points of the lecture using text and illustrations written and drawn from a sequence of transparencies placed on an overhead projector, and points out the key features while giving a verbal explanation. Figure 1 is an example of such a display: an illustration showing two views of a CANDU fuel bundle with the main components identified on the diagram, and the text of the key points that the lecturer wants to make when presenting this part of the lecture.

In a distance learning environment the students should be able to replicate the delivery of the lecture content that would be experienced in the classroom. We have found that playing back a videotape is not a satisfactory approach: the usual classroom environment does not lend itself to a quality production, stopping and replaying parts of the lecture that were not well understood was rather time consuming. It is our view that the passive watching of a videotape does not provide an acceptable learning environment.

To allow an individual student to experience via his/her computer the actions taken by the lecturer in making a presentation using overhead displays, the following elements need to be allowed for:

- select for display any of the pages used in the lecture
- select any of the key points on a given display page and observe the features that the lecturer wants to highlight
- listen to what the lecturer says for each key point.

Figure 2 shows the interactive features that were added to the page in Figure 1 to realize the above functions:

- buttons at the top and bottom margins of the display provide the means to navigate between pages

- selection of the "arrow icon" next to each key point shows the highlights for that item (item 1 in Figure 2, as indicated by the arrow icon being dark)
- selection of the "speaker icon" plays the sound recording for that particular item (speaker icon turns dark and sound controller displayed at the top of the page).

The software used to produce the interactive displays is Adobe Acrobat Exchange; it allows the creation of "buttons", labels and other highlights, as well as all the interactions that we found necessary to simulate the lecture environment. The methodology used requires only minor format changes to the original illustrations that were prepared for overhead projections, then each page was converted into a portable document format (pdf) document by the Adobe Acrobat Writer. Each page was subsequently combined with a pdf template that contains the interactive buttons and icons. While each page required some customization, in most cases these were not time consuming. The preparation of the scrip and the recording of the sound files was the main additional effort that was required to convert a static page of text and diagram to an interactive multimedia display.

The resultant course material allows each student to proceed at his/her own pace, selecting each element of the lecture for as long as needed, and repeating it as often as necessary. The sound recordings are also made available in text form, so students have the option of reading and/or listening to the lecturer's words, making their owns notes and highlights on the hard copy, and being able to search for key words and expressions. All of these elements, including the student's interaction with the computer, listening, reading, and making notes, contribute to better learning as the student uses more of his senses and is able to progress at a speed and sequence that is best suited to his individual learning needs.

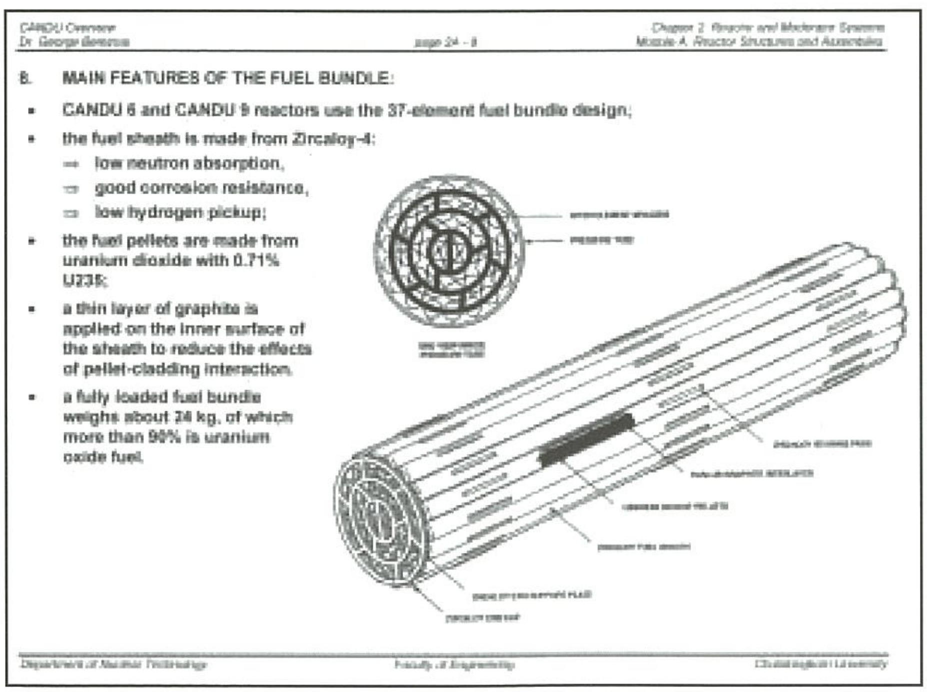



*Figure 1. Typical lecture illustration used with overhead projector.*

The authors have converted a course from the classroom lecture delivery format to interactive multimedia using the above methodology. The original pages containing text and diagrams were prepared in Microsoft Word and converted to pdf files. Other illustrations, whether originally drawn by a graphics or word processor program, or scanned, were also converted to pdf. The individual sound recordings were typically of one minute duration, with the longest requiring about two minutes. The production effort for the course was in the order of 800 person hours, i.e. a 20:1 ratio of producing an interactive multimedia version of a typical 40 hour one-semester course.

The complete software for the course requires about 600 megabytes, and therefore can be placed on a single CD-ROM. The Adobe file format is also compatible with the Internet, but because of the size of the sound files and the limited speed and accessibility of the Internet in Thailand and in many of the other countries in Asia where the course is delivered, we are using CD-ROMs, for the time being, as the medium of distribution to our students.

## Course Delivery

Although the distance learning format allows great flexibility over the timing of the course, our target was to meet the needs of a semester-based curriculum. Because we believe that the self-paced interactive nature of the course design provides a superior learning environment over the classroom setting for the majority of the students, we offer the course in the self-paced format both at our own campuses and at locations away from our campuses.

At Chulalongkorn University, the department's computer room is reserved for the three hour period identified for our course on the time table. It is optional for the students to study the course material at that time and place, but most of them take advantage of knowing that the lecturer is available at that time to answer questions and to provide assistance. At other times, the students are encouraged to use e-mail to ask questions and to submit the weekly assignments, and the lecturers' answers and feedback on the assignments are also provided via e-mail. Typically once a month we meet in a classroom to discuss common problems and provide remedial material as needed.

At McMaster University, this course is offered as a regular course at the graduate student level in the Department of Engineering Physics on a self-paced basis, augmented by one-on-one, email, and ad-hoc discussion groups as required. It can be used for credit as a Continuing Education course, for the Nuclear

Technology Diploma, for the Master's of Engineering Degree and the Ph. D. degree. Since the Faculty of Engineering at McMaster has reciprocal agreements with a number of other Canadian Universities, the course can be used for credit in engineering degrees at those universities. A number of professionals from industry have taken this CD-ROM based course as well as classroom-based courses offered by McMaster.

When the course is offered at a campus other than Chulalongkorn University or McMaster University, one of the course authors travels to that campus at the start of the semester in order to meet the designated local teaching partner(s) and the students, and to ensure that the students gain the necessary familiarity with the interactive learning technology. In most cases the students will submit the weekly assignments to their local lecturer, who keeps in e-mail contact with the course authors, but there are also provisions for the students to contact the course authors directly. At the end of the semester one of the course authors returns to the host campus to resolve any outstanding problems and to participate in the conduct of the final examination.

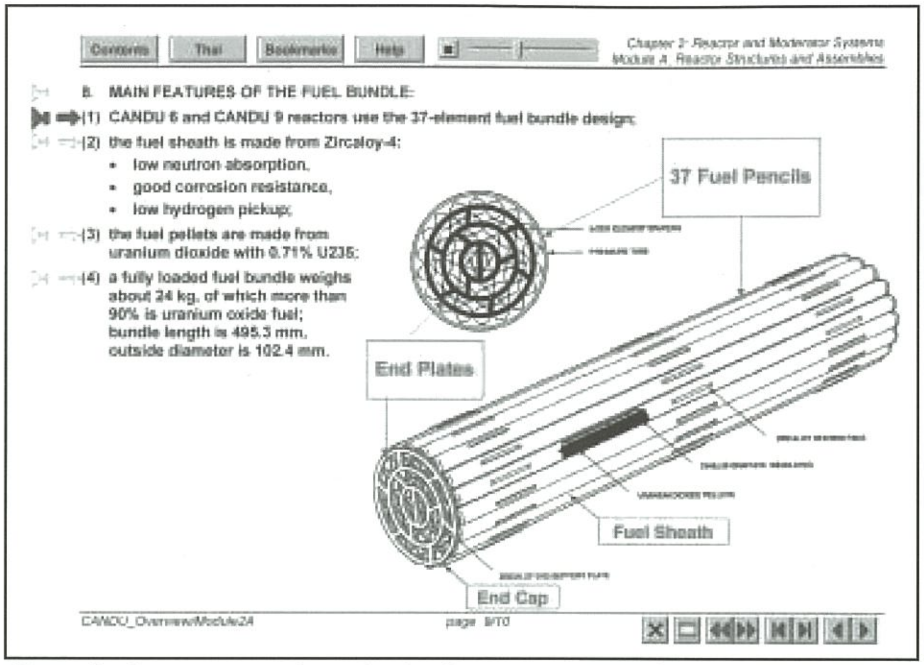



Figure 2. Interactive multimedia display page adapted from Figure 1

An important aspect of engineering education is to ensure that the students gain the practical experience necessary for the full mastery of a particular subject. In the case of nuclear power plants such practical experience is commonly gained with the use of simulators that replicate the behaviour of the power plant under normal as well as abnormal conditions. Such a simulator is used as part of the course the authors teach on Nuclear Power Plant Systems and Operation. The course has been delivered at the following institutions:

- Chulalongkorn University, Bangkok, Thailand
- Prince of Sonkhla University, Sonkhla, Thailand
- Gadjah Mada University, Yogyakarta, Indonesia
- Bandung Institute of Technology, Bandung, Indonesia
- University of the Philippines, Manila, the Philippines
- Shanghai Jiatong Technical University, Shanghai, China
- Xian Jiatong Technical University, Xian, China
- Tsinghua University, Beijing, China
- Hanoi National University, Hanoi, Vietnam
- McMaster University, Hamilton, Canada.

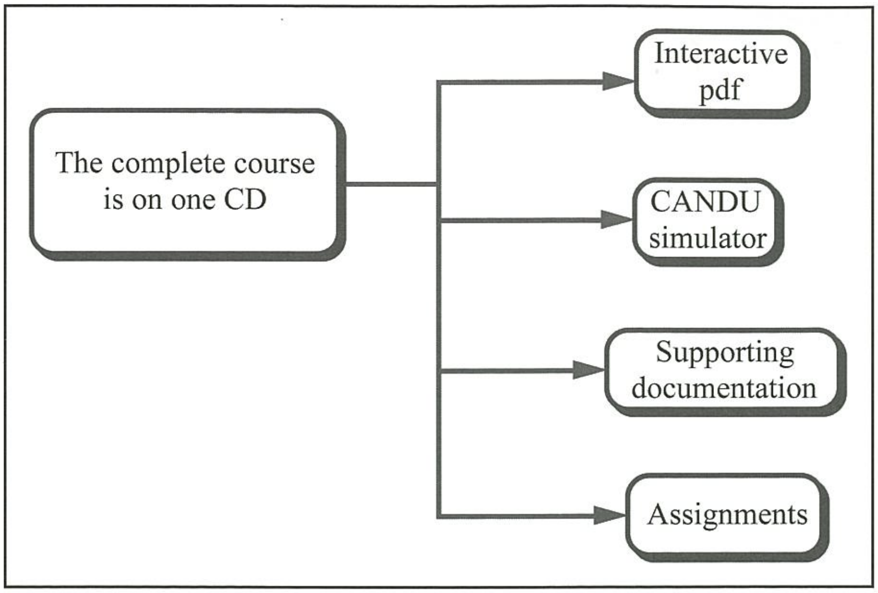
## Does It Work?

As discussed, this self-paced CD-ROM course methodology is well suited to the task of information delivery and provides a higher degree of student involvement that traditional lecture style courses. Engagement of the learner's mind in integrative tasks is key to learning, so, in this regard, the format is a demonstrated success. It is also appropriate that the instructor's time is freed from the 'content delivery' task and can now be better spent on tasks that are more hands-on and interactive, such as individual mentoring, group discussions, material development and augmentation, and student monitoring and assessment.

As might be expected, some students report that they feel more disconnected from the rest of the class than is the case with a traditional lecture-based course. It is apparent that the more high-tech the format is, the more high-touch [3] the course as a whole needs to be. Regular discussion groups are recommended as a means of compensation. Email and electronic forums have also proven to be effective in providing asynchronous and synchronous discussion platforms. The class dynamic is different with these platforms and can lead to more thoughtful exchanges than might be possible otherwise.

This CD-ROM format is not suitable for student assessment, nor was it intended to be. Traditional methods (assignments, plus invigilated tests and exams) continue to be used to ensure that the course meets the university accredited course standard. There is no reason, however, that testing cannot be conducted at remote testing centres as long as they are recognized by the host universities.

Yes, it works! The knowledge of subject matter experts is brought to the learner, instructors are effectively utilized and learning is taking place that is on par or better than traditional methods. Coupled with electronic communication (email, conferencing, etc.) and discussion groups, it has proven to be an effective learning tool for universities and for industry.




## Conclusions

The global economy will increasingly demand that education and training be delivered where and when required by the subject matter experts best able to provide the information and the learning experience. The vast amount of information that the future practitioners of the nuclear power industry need to be aware of will be increasingly difficult to disseminate with the traditional classroom-based education and training methods. Almost all of the documents required for the design, analysis, procurement and operation of a nuclear unit are now generated by computer, and increasingly such information is accessible where and when needed via the company Intranet or Internet.

The authors have developed and implemented a method of multimedia interactive learning methodology which they believe is well suited to facilitate the transition from classroom-based to distributed education. The Adobe portable document format has been found to be a suitable software package into which course material produced by any word processor, graphics, spread-sheet and similar programs, as well as scanned documents, can be converted. Adobe Acrobat Exchange has the tools to add the necessary interactive features to the pdf files. The course the authors produced in this format has been delivered at ten universities in six countries.

A sample of the course can be found at http://epic.mcmaster.ca/~garlandw/ under the link for course EP704.

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# The Nuclear Engineering Programmes at the Royal Military College of Canada

*by Hugues W. Bonin*

***Ed. Note:*** *Because of space limitations we are splitting Prof. Bonin's article into two parts so that we might preserve his unique two language format. Part 2 will be published in the next issue of the CNS Bulletin.*

The last years have been eventful for the staff and students in the nuclear engineering programmes at the Royal Military College of Canada (RMC) in Kingston, Ontario. Among the several changes is the accessibility of the graduate programmes to civilian (Canadian citizens) students, a fact that is little known outside RMC since, in the past, these graduate programmes were intended only for military personnel. Another major event is the accreditation of the graduate programmes offered by the Department of Chemistry and Chemical Engineering (chemical, nuclear and environmental science and engineering) by the Ontario Council of Graduate Studies.

A glance at the internet sites of the Canadian universities offering nuclear engineering programmes (all at the graduate level) reveals that, in terms of teaching and research staff numbers, student populations and research activities, RMC ranks presently among the top universities, if not the very first. At the last CNS-CNA student conference in June 2001, half of the total number of student papers presented were by RMC students, some of them winning the best paper awards at the Master's degree and the undergraduate levels. How was this successful status achieved?

Nuclear engineering has been part of the undergraduate chemical engineering curriculum since the mid 1960s, with two fourth year courses given within the chemical engineering programme, along with supporting laboratory experiments. In the mid-1970s, RMC became officially bilingual, and all undergraduate engineering programmes were taught in both English and French, such that a given student had the choice of taking all his courses in English, or in French, or even as a mixture of both languages when possible. The word "his" has been used in the previous sen-

*Campus of the Royal Military College of Canada, Kingston, Ontario.*
*Campus du College militaire royal du Canada de Kingston, Ontario.*

# Les Programmes De Génie Nucléaire Du Collège Militaire Royal Du Canada

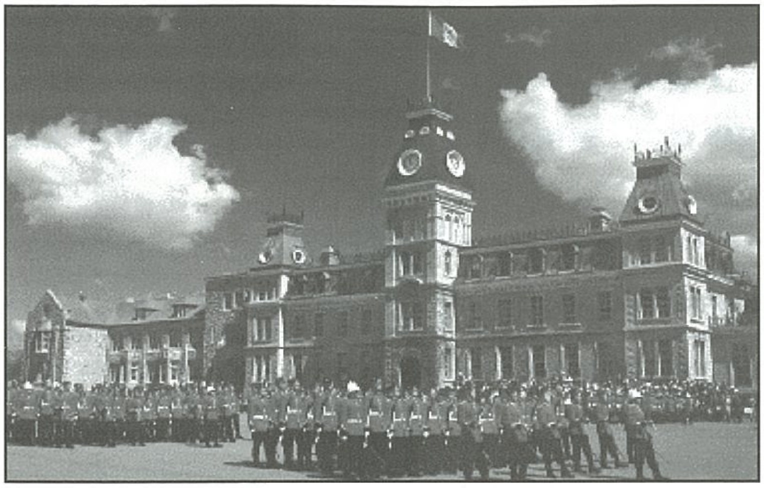
*par Hugues W. Bonin*

***Note de l' Èditeur:*** *¿ cause du manque d'espace, nous coupons l'article du Prof. Bonin en deux, afin de prÈserver son unique format bilingue, et n'incluons ici que la premiËre partie. La deuxiËme partie de l'article sera publiÈe dans le prochain numÈro du Bulletin de la SNC.*

Les dernières années ont été mouvementées pour le corps enseignant et les étudiants des programmes de génie nucléaire du Collège militaire royal du Canada (CMR) de Kingston, Ontario. Parmi les nombreux changements figure l'accessibilité récente aux programmes de cycles supérieurs aux étudiants civils (citoyens canadiens), un fait très peu connu hors campus puisque, jusqu'à récemment, ces programmes de maîtrise et de doctorat n'étaient réservés qu'aux membres des Forces armées canadiennes. Un autre événement majeur est l'accréditation des programmes d'études supérieures offerts par le Département de chimie et de génie chimique (i.e. science et génie chimique, nucléaire et environnemental) par l'"Ontario Council of Graduate Studies".

Un survol des sites internet des universités canadiennes offrant les programmes de génie nucléaire (tous de cycles supérieurs) révèle que, en termes de la taille du corps professoral et de la population estudiantine, de même que de l'intensité des activités de recherche, le CMR se classe parmi les premières universités, quand ce n'est pas la toute première. À la dernière conférence étudiante de la SNC et de l'ANC en juin 2001, la moitié du nombre de présentations provenait d'étudiants du CMR, certains d'entre eux se méritant les prix des meilleures présentations au niveau des premier et deuxième cycles. Comment en est-on parvenu à ce succès?

Le génie nucléaire a constitué une partie du programme de premier cycle en génie chimique depuis le milieu des années soixante, avec deux cours de quatrième année offerts aux élèves-officiers, en plus de laboratoires en soutien à ces cours. Au milieu des années soixante-dix, le CMR est devenu officiellement bilingue, et tous les programmes de premier cycle en génie ont commencé à être donnés dans les deux langues officielles du Canada, de telle sorte tence since at that time the three military colleges in Canada were accessible only to male students. The colleges became co-ed in 1980. With bilingualism came a major expansion of RMC's teaching and research floor space, with the building of the five-module Sawyer Science/Engineering Complex. The Department then occupied all five floors of Module 5 (plus additional space in other buildings), and, as part of the building plans of Module 5, were included nuclear laboratories with provision for a Reactor pool for a SLOWPOKE-2 nuclear reactor. Budgetary constraints within the Department of National Defence postponed the acquisition of the reactor to 1985.



*Graduation parade, Royal Military College of Canada.*
*Défilé de la graduation, Collège militaire royal du Canada.*

The graduate nuclear engineering programme started in 1978 with the arrival of the first student at the Master's degree level. Since then, 32 Master's degree students have graduated. The Ph.D. program was initiated in 1991 and two students have graduated since then. At the time of this writing, there are three students in progress at the Master's degree level, and three at the Ph.D. level in nuclear engineering. In addition, some of the teaching staff members supervise graduate studies for students registered at nearby Queen's University.

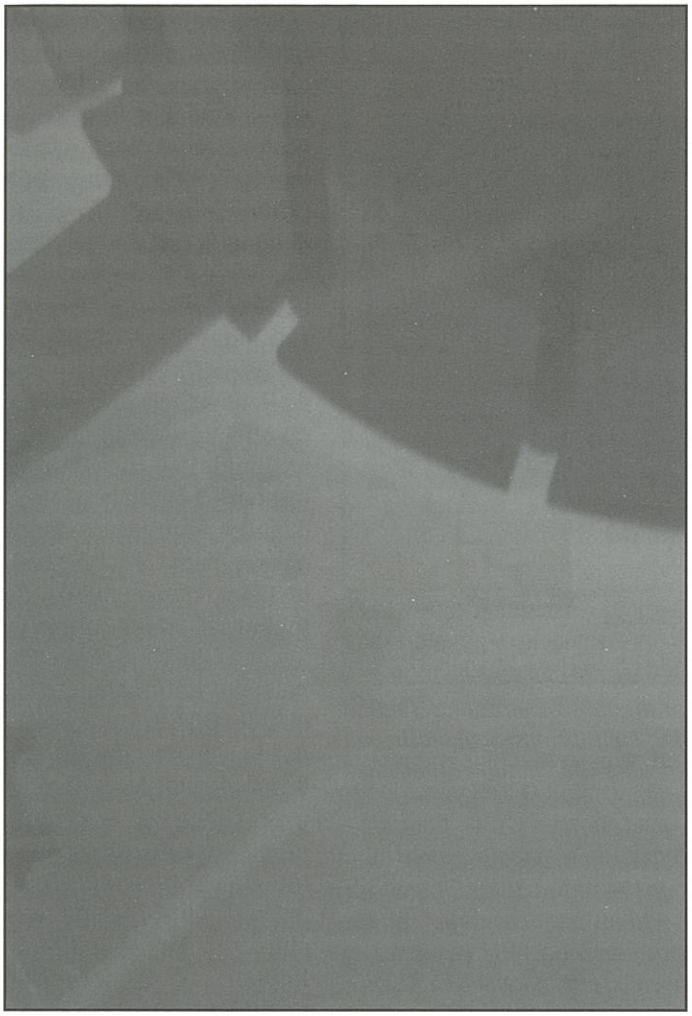
Initially, the graduate programme was reserved for "sponsored" officers of the Canadian Forces. The term "sponsored" means here that the graduate degree is part of the preparation needed to make the officer competent in a given posting or "military occupation". In this programme of sponsored studies, a military posting that would be vacated two years down the road is identified as becoming available and advertised to career managers and throughout the Forces. Interested officers would then apply for the position, and a competition would then be run among eligible officers. Once accepted by the Forces, the candidate would then apply for admission at RMC's Graduate School, and it is only when formally admitted that the officer would be posted for the 21-month Master's degree program, or longer for a Ph.D. Upon graduation, the officer then serves at the posting requiring the graduate degree, for a period of typically four years. The graduate student receives his or her officer's pay during his or her stay at RMC, and all tuition fees are paid by the Forces. In the early years, there was only one military occupation requiring a Master's degree in nuclear engineering, now there are five.

A population of "unsponsored" graduate students now equals the former group. These may be military officers or non-commissioned officers, and civilians. Some of them are part-time students, and all have to pay tuition fees

que chacun des étudiants a le choix de prendre tous ses cours en Français ou en Anglais, ou même selon un mélange de cours donnés dans les deux langues. Le masculin est utilisé dans la phrase précedente puisqu'à cette époque, les trois collèges militaires du Canada n'acceptaient que des jeunes hommes comme étudiants. Le collège devint accessible aux jeunes femmes en 1980. Avec le bilinguisme arriva une expansion importante des bâtiments du campus de Kingston, avec la construction du complexe de génie/science Sawyer qui compte cinq modules. Le Département s'est alors installé sur les cinq étages du Module 5, de même que sur certains étages de d'autres édifices. De plus, les plans et devis du Module 5 comprenaient des laboratoires nucléaires et l'installation d'une piscine en prévision de l'arrivée d'un réacteur nucléaire SLOWPOKE-2. Les contraintes budgétaires du Ministère de la Défense ont reporté l'acquisition de ce réacteur à 1985.

Le programme d'études supérieures en génie nucléaire démarra en 1978 avec l'arrivée du premier étudiant au niveau de la maîtrise. Depuis lors, on a eu 32 diplômés en maîtrise et deux diplômés au doctorat, le programme de doctorat ayant débuté en 1991. Présentement, trois étudiants poursuivent leurs études en maîtrise et trois autres au doctorat. Il faut mentionner aussi que quelques-uns des professeurs supervisent les travaux de recherche d'étudiants inscrits aux programmes de cycles supérieurs de l'Université Queen's de Kingston.

Au tout début, le programme d'études supérieures était réservé aux officiers "commandités" des Forces canadiennes. Le terme "commandité" signifie ici que la formation et le diplôme d'études supérieures sont un prérequis à l'affectation de l'officier à un poste spécifique au sein des Forces, afin de lui procurer les compérences nécessaires à l'accomplissement de ses tâches. Dans ce programme d'études commanditées, une affectation militaire que l'on prévoit devenir libre dans deux ans est identifiée comme disponible et annoncée aux gérants de carrière et partout au sein des Forces. Les officiers intéressés posent alors leurs candidatures à ces affectations, et concourent pour elles. Une fois acceptés par les Forces, ils postulent alors leur admission à l'École des études supérieures du CMR, et ce n'est qu'une fois admis académiquement que ces officiers sont formellement affectés au CMR pour la durée de la maîtrise de 21 mois, (ou plus longue dans le cas du doctorat). À la graduation, l'officier rejoint son affectation pour une durée typique de quatre ans. Durant son séjour au CMR comme étudiant, l'officier reçoit sa solde normale, et



*Epoxy samples being irradiated in the pool of the SLOWPOKE-2 reactor, in the blue Cerenkov light.*
*Échantillons d'époxies irradiés dans la piscine du réacteur SLOWPOKE-2, dans la lumière bleue de l'effet Cerenkov.*

which are relatively modest. Full-time "unsponsored" students are eligible to NSERC scholarships (since RMC has recently become eligible to NSERC funding) and to similar scholarships offered by the Department of National Defence under the Defence Research and Development Branch (DRDB) programme. Details of these scholarship programmes may be found on the appropriate internet sites (www.nserc.ca and www.rmc.ca , respectively). Usually most of these students find employment as research assistants for on-going research projects at RMC. As mentioned earlier, there are no longer restrictions to enrolling civilian students in the graduate programmes at RMC other than the need for these students to be Canadian citizens, and, of course, have a strong and relevant academic background.

RMC offers Master's degree and Ph.D. programmes in both nuclear science and engineering. The details of these programmes may be found at the web site of RMC, and the courses and programme regulations are found in the Graduate Studies and Research Calendar, which could be obtained through the internet or by phone. Normal course

ses frais de scolarité sont entièrement payés par les Forces canadiennes. Initialement, il n'y avait qu'une seule affectation demandant comme prérequis une maîtrise en génie nucléaire, il y en maintenant cinq.

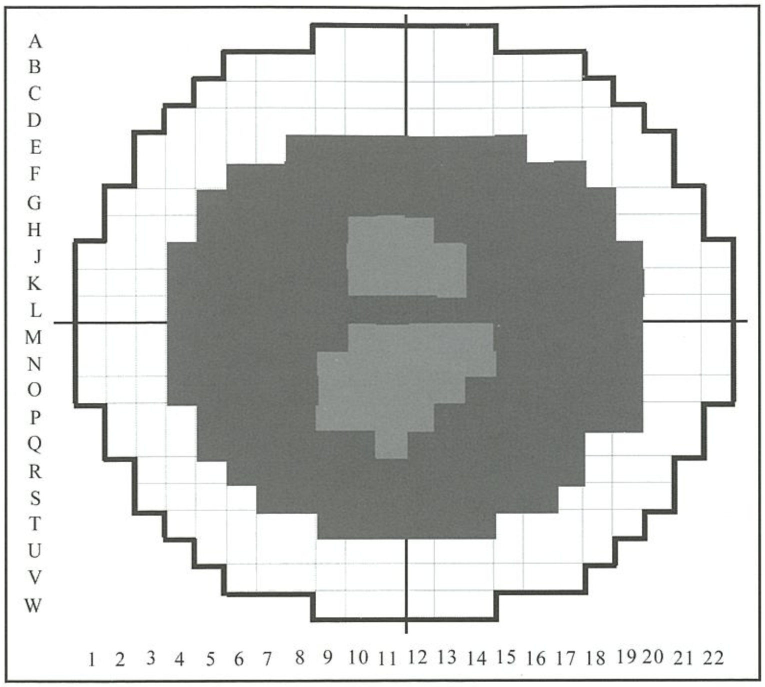
Le premier groupe d'étudiants est maintenant augmenté par le groupe d'étudiants "non commandités". Ceux-ci sont des officiers ou des sous-officiers des Forces canadiennes, et des civils. Certains d'entre eux sont des étudiants à temps partiel, et tous doivent payer des frais de scolarité qui sont relativement modestes. Les étudiants "non commandités" à temps plein sont éligibles pour les bourses d'études du CRSNG (puisque le CMR est récemment devenu éligible aux subventions du CRSNG), et des bourses d'études comparables sont offertes par le Ministère de la défense nationale dans le programme de l'Agence de la Recherche et du Développement de la Défense (ARDD). On trouvera les détails de ces programmes de bourses d'études aux sites internet appropriés (www.crsng.ca et www.rmc.ca , respectivement). D'habitude, la plupart de ces étudiants se trouvent de l'emploi comme assistants de recherche pour l'un ou l'autre des projets de recherche en cours au CMR. Comme on l'a mentionné ci-haut, il n'y a plus de restriction à l'inscription d'étudiants civils aux programmes d'études supérieures du CMR autres que le besoin pour ces étudiants d'être citoyens canadiens et, bien sûr, d'avoir un dossier académique solide et pertinent.

Le CMR offre des programmes de maîtrise et de doctorat tant en sciences nucléaires qu'en génie nucléaire. On pourra trouver les détails de ces programmes au site internet du CMR, et la description des cours offerts se trouve à L'Annuaire de la Division des études supérieures et de la recherche disponible auprès du Secrétaire général du CMR et que l'on peut se procurer via l'internet ou par téléphone. Le nombre de cours requis normalement pour la maîtrise est de cinq cours d'un semestre de niveau supérieur. Ceux-ci proviennent d'habitude du groupe de cours suivants: CC511 Health Physics and Radiation Protection, CC515 Nuclear Detection and Measurement, CC523 Nuclear Reactor Engineering, CC525 Nuclear Reactor Safety, et CC565 Nuclear and Radiochemistry. (Les titres anglais de ces cours ne signifient pas qu'ils ne sont pas disponibles en Français: ils pourront se donner en Français sur demande et selon les disponibilités). On offre de plus de nombreux autres cours plus spécialisés couvrant des sujets tels que l'ingénierie des combustibles nucléaires, la gestion du combustible nucléaire, la radiographie neutronique et la gestion des déchets radioactifs. Enfin, on doit mentionner qu'il existe une entente du CMR avec l'Université Queen's selon laquelle un étudiant de l'une ou l'autre institution peut suivre des cours offerts par l'autre université.

Le corps enseignant en science et génie nucléaires est constitué de six professeurs à temps plein: Messrs. William S. Andrews, Les G. I. Bennett, Hugues W. Bonin, Brent J. Lewis, le ltv Martin Pierre et M. Sadok Guellouz, ce dernier s'étant joint récemment au personnel enseignant du Département de génie mécanique. Il y aussi trois professeurs affiliés: M. Ron G. Hancock, Mme Diana Wilkinson requirements for an engineering student at the Master's degree level are five one-term graduate courses. These are usually among the following courses: CC511 Health Physics and Radiation Protection, CC515 Nuclear Detection and Measurement, CC523 Nuclear Reactor Engineering, CC525 Nuclear Reactor Safety, and CC565 Nuclear and Radiochemistry. There are many other specialized courses, such as in nuclear fuel engineering, nuclear fuel management, neutron radiography and nuclear waste management. In addition, there is an agreement between RMC and Queen`s University by which students from either institutions may take courses from the other university.

The teaching staff is composed of six full-time professors: Drs. William S. Andrews, Les G.I. Bennett, Hugues W. Bonin, Brent J. Lewis, Lt(N) Martin Pierre and Dr. Sadok Guellouz who recently joined the Department of Mechanical Engineering. There are also three adjunct professors: Drs. Ron G. Hancock, Diana Wilkinson and Major William J. Lewis. In addition to their teaching and thesis supervision duties, these persons are pursuing research in a wide variety of domains, supported by research grants from NSERC and the Academic Research Program (ARP) of the Department of National Defence. Other sources of research funding include research contracts for various agencies of the Department of National Defence (such as the Director General of Nuclear Safety-DGNS), research contracts with the nuclear industry and consultation activities. In the most recently available issue of the Commandant's Report, Part III (FY1999-2000), nuclear-related research funding was reaching some $464,000 for that fiscal year.

The teaching and research staff share the following research areas: radiochemistry and neutron activation analysis, radiation effects on materials, radiation processing of polymers, neutron radiography, nuclear reactor simulation, analysis and design, CANDU fuel bundle optimal design, nuclear fuel cycles and management, nuclear fuel engineering and behaviour, including fission product release



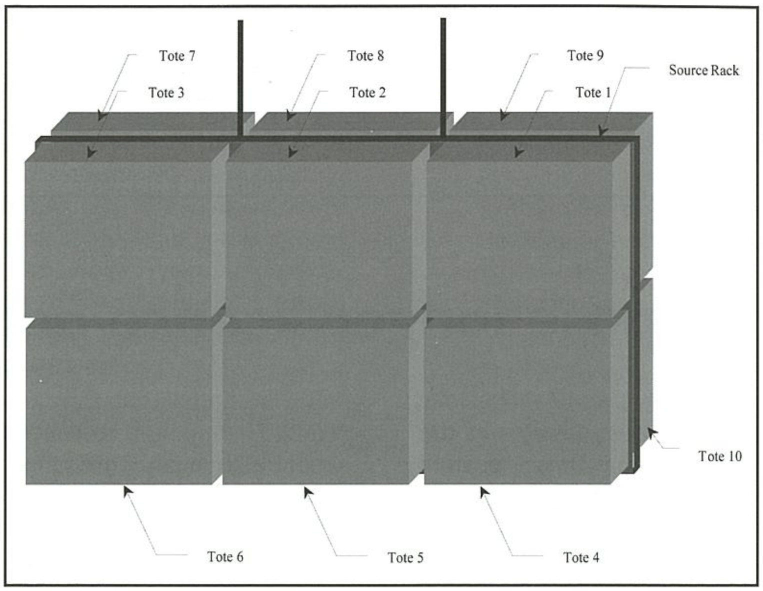

*Optimal in-core fuel management of a natural uranium fuelled CANDU reactor at approach to refuelling equilibrium: schematic end view of a 600-MWe CANDU reactor showing the channels that have been refuelled twice (in red), once (in blue) or not yet (in white), at refuelling cycle #232.*
*Gestion optimale en-pile du combustible d'un réacteur CANDU alimenté à l'uranium naturel à l'approche de l'équilibre de rechargement: vue shématisée du réacteur CANDU de 600 MWe montrant les canaux de combustible rechargés deux fois (en rouge), une fois (en bleu) et non encore rechargés (en blanc) au cycle de rechargement #232.*

et le Major William J. Lewis. En plus de leurs tâches d'enseignement et de supervision de thèses, ces personnes sont actives en recherche dans une grande variété de domaines, avec le support financier provenant de sources telles que les subventions du CRSNG, et celles du PRU (Programme de Recherche Universitaire du Ministère de la défense nationale). Les professeurs bénéficient aussi d'autres sources de fonds pour leurs recherches, incluant des contrats de recherche pour diverses agences du Ministère de la défense nationale (telles que le Directorat général de la sûreté nucléaire), des contrats de recherche avec l'industrie nucléaire, et des activités de consultation. On peut constater dans la plus récente version du Volume III du Rapport annuel du Commandant de CMR (AF 1999-2001) que le total des subventions pour la recherche pertinente au nucléaire s'élevait à environ $464,000 pour cette année fiscale.

Le personnel enseignant et de recherche se partage les domaines de recherche suivants: la radiochimie et l'analyse par activation neutronique, les effets des radiations sur les matériaux, le traitement des polymères par le rayonnement, la radiographie neutronique, la simulation, l'analyse et le désign de réacteurs nucléaires, la conception optimale de grappes de combustible CANDU, les cycles de combustible avancés CANDU et la gestion optimale du combustible, l'ingénierie et l'étude du comportement du combustible nucléaire, incluant la modélisation du relâchement des produits de fission, les applications de l'intelligence artificielle aux systèmes nucléaires, la réponse aux accidents nucléaires, la détection et la mesure des radiations, la radioprotection, la dosimétrie, et le contrôle des réacteurs nucléaires.

Le Département de chimie et de génie chimique est très bien pourvu en équipements soutenant l'enseignement et la recherche en science et en génie nucléaires. La pièce maîtresse est bien sûr le réacteur nucléaire SLOWPOKE-2 qui fut mis en service en septembre 1985, étant le premier à être muni d'un nouveau combustible basé sur des modelling, artificial intelligence applications to nuclear systems, nuclear accident response, nuclear radiation detection and measurement, health physics, dosimetry and radiation protection, and nuclear reactor control.

The Department of Chemistry and Chemical Engineering is well provided with equipment supporting the academic program in nuclear science and engineering and the research. The main piece is of course the SLOWPOKE-2 nuclear reactor commissioned in September 1985 and the first with the new fuel elements based on 20%-enriched UO2 pellets. It is estimated that this more performing fuel will permit the operation of the reactor to probably year 2020 before refuelling. The reactor facility was equipped with a neutron radiography system based on an in-house designed neutron beam tube. This system is mostly used for the non-destructive periodic examination of military aircraft wing components. Another key piece of equipment added to the reactor facility is a device called "elevator" which positions large samples in the reactor pool for their irradiation. The nuclear laboratory has been equipped with several neutron activation analysis detector/counting suites based on personal computers. Several other pieces of radiation detection and counting equipment are also provided in support to teaching and research, such as bubble dosimeters, radioactive sources for calibration and other uses, and, very important, an expensive Tissue Equivalent Proportional Counter (TPEC) supporting a major research project on the determination of radiation doses received by the crews of high altitude aircrafts. For computing facilities, students and staff benefit from up-to-date equipment supplied by the College, supplemented by specialized equipment obtained through research funding. Most of the PC-based equipment, plus several larger workstations, are interconnected through the College local area network, which makes possible access to the internet. All this equipment has the usual software (such as Microsoft Office), and many nuclear codes are available, either commercially available codes such as MCNP 4A and Microshield 5(tm) , or in-house developed software. AECL-based codes are also on-site (WIMS-AECL, VICTORIA, and ORIGEN, among others), and more codes (on thermalhydraulics notably) are on their way to RMC thanks to the kind support of AECL.




*Detail of a gamma irradiator being designed for the destruction of spent plastic explosives.*

*Détail d'un irradiateur gamma en conception pour détruire des explosifs plastiques usés.*

pastilles d'UO2 enrichies à 20% en uranium-235. On estime que ce combustible plus performant permettra l'exploitation du réacteur jusqu'en 2020 environ avant qu'il ne faille changer le coeur du réacteur. Le laboratoire SLOWPOKE-2 a été pourvu d'une installation de radiographie neutronique basée sur un tube à faisceau neutronique conçu au CMR. Ce système sert surtout à l'examen périodique non-destructif de composantes d'ailes d'avions militaires. Une autre pièce d'équipement importante est un système de positionnement d'échantillons de grande taille, appelée "ascenseur", qui permet de placer et de maintenir des objets dans la piscine du réacteur pour la durée de l'irradiation. Le laboratoire nucléaire est aussi très bien équipé de plusieurs systèmes informatisés de détection et de comptage gamma pour l'analyse par activation neutronique. De nombreux autres systèmes de détection des radiations sont disponibles en soutien à l'enseignement et à la recherche, tels que des dosimètres à bulles, des sources-étalons radioactives, et un dispendieux système de compteur proportionnel équivalent au tissu vivant, clef de voûte d'un important projet de recherche sur la mesure des doses de radiation reçues par les équipages des avions de ligne volant à hautes altitudes. En matière de ressources informatiques, les étudiants et chercheurs bénéficient de l'équipement dernier cri fourni par le CMR, en plus de certains équipements spécialisés obtenus grâce aux fonds de recherche. Presque tous les ordinateurs sont interconnectés au réseau informatique du CMR qui permet aussi de se raccorder à l'internet. Tout cet équipement est muni des logiciels courants, comme la suite Microsoft Office, et plusieurs logiciels spécialisés en nucléaire sont aussi disponibles, comme des codes commerciaux tels que MCNP 4A et Microshield 5™. Plusieurs codes de l'ÉACL sont aussi installés sur nos ordinateurs, comme, par exemple, WIMS-AECL, VICTORIA, et ORIGEN. D'autres codes (en thermohydraulique notamment) vont arriver sous peu grâce à la bienveillante collaboration d'ÉACL.

# GENERAL news

## CNSC staff propose longer licence periods

At the March 1, 2002, meeting of the Canadian Nuclear Safety Commission, Mike Taylor, executive director of the Office of Regulatory Affairs, proposed a "more flexible basis for recommending licence periods". For nuclear power plants he recommended a licence period of five years (compared to the typical two-year period now.) and suggested that when proposed periodic safety reviews are introduced the period could be extended. For radioisotope licences he proposed that the licence period could be from five years to indefinite.

"The objective", he said, "is to provide a consistent, rational basis which recognises the relative risk posed by the facility, activity or equipment being licensed, the time required for staff to conduct a thorough review, and the need for transparency." "Staff considers that adoption of this approach can lead to improved effectiveness and efficiency of the licensing process while maintaining an appropriate level of public transparency", he added. The longer periods, he said, would be associated with a revised basis for licensing, based on a "risk informed" approach. (The USNRC has been moving towards risk-informed regulation for several years.)

Taylor noted that this approach was more logical and would free up staff to concentrate on real safety issues. It would also mean more emphasis would be placed on compliance. He pointed out that Canada is the only country with such short licence periods for nuclear plants.

Some of the Commissioners did not appear to be impressed. "This reflects a staff and industry view, not that of the public or the Commission", Commission member Christopher Barnes commented. Commission member Yves Giroux added that the Commission would lose "face to face" meetings with licensees and intervenors. Commission member Alan Graham echoed this view, stating that the move would "eliminate the last tier of review".

Subsequently, on April 15, 2002, CNSC staff issued an Information Bulletin (No. 02-03) with their two Commission Member Documents, CMD 02-M12 and CMD 02-M12.A , seeking comments on this proposal, with a deadline of May 31.

To obtain a copy of this Bulletin or to submit comments send an e-mail to: regaffairs@cnsc-ccsn.gc.ca.

The matter will be discussed further in future meetings of the CNSC.

## Corrosion found in US reactor vessel head

On March 18, 2002, the United States Nuclear Regulatory Commission (USNRC) issued a Bulletin (#2002-01) to all nuclear plant licensees as a result of the discovery of corrosion in the head of the reactor vessel of the Davis-Besse plant. Davis-Besse is a 935-MWe Babcock & Wilcox PWR located in Oak Harbor, Ohio.

The cavity was discovered on March 7 during a refuelling outage as workers were completing NRC-ordered inspections of nozzles on the vessel head. The outage had started on February 16, and the inspections were being done to satisfy requirements of an NRC bulletin issued in August 2001 titled "Circumferential Cracking of Reactor Vessel Head Penetration Nozzles." During the outage, while workers were inspecting 69 control rod tubes that pass through the head, cracks were found through the walls of three tubes, and lesser cracks were discovered in two additional tubes. The cavity was discovered nearby.

The cavity measured about 4 in. by 5 in. and was approximately 6 in. deep into the 6 1Z2-in.-thick vessel head. The head, which is 17 feet in diameter and weighs about 150 tons, is made of carbon steel and has a stainless steel liner.

The preliminary cause of the cavity was attributed to corrosion as a result of boric acid deposits. Boric acid was apparently deposited on the vessel head through a leaking crack in a control rod tube or through aging seam welds surrounding the tubes. The acid did not penetrate the stainless steel liner. Boric acid is added to the water of a pressurized water reactor's coolant system as an absorber for reactivity control.

The various plants that responded to the NRC Bulletin reportedly detected no deterioration of their vessels. However, some of the utilities intend to conduct bare-metal inspections to be prudent.

# French Academy criticizes LNT

*Ed. Note: In November 2001 the French Academy of Medicine issued a position paper they titled "Medical irradiation, radioactive waste, and disinformation: The position of the French Academy of Medicine". It began with the statement: "The French Academy of Medicine, preoccupied by the concerns that arose in the public regarding medical exposure to X rays and radioactive waste in the environment, and by erroneous information that these topics give rise to, wishes to express its position."*

*Following are the Recommendations from that statement.*

### ~ Recommendations ~

### The French Academy of Medicine:

1— recommends increasing efforts in radiation protection in the area of radiological examinations, on the one hand to reduce received doses from certain types of examinations (CT scans of children, interventional radiology, lung X-ray examinations of premature infants, etc...) and on the other hand, to allow radiology departments, notably in radio-paediatrics, to benefit from a staff well trained in dosimetry and capable of ensuring the quality control of equipment, in a way similar to that previously done with mammography in breast cancer screening. It also recommends reducing patient exposure through increased clinical and technical research in this area and improved training.

2— recommends an effort in fundamental research: on the biological mechanisms activated by the repair of the DNA damage after low doses up to 100 mSv; and on the effects of these doses on the exchanges of intra- and inter-cellular molecular signals.

3— denounces the utilization of the linear no-threshold (LNT) relation to estimate the effect of doses lower than a few mSv (equivalent to variations of natural radiation in France) and of doses hundreds of times lower, such those caused by radioactive waste, or 20 times lower, such as those resulting in France from radioactive fallout from the Chernobyl accident. In agreement with many international institutions, the Academy denounces the improper use of the concept of the collective dose to this end, since these procedures are without any scientific validity, even if they appear to be convenient for administrative purposes.

4- subscribes to the conclusions of the 2000 Report of the Scientific Committee of the United Nations (UNSCEAR) concerning the analysis of health consequences of the Chernobyl accident, and denounces the propagation of allegations purporting an excess in cancers other than that of the thyroid, and an excess of congenital malformations.

5— recommends the introduction of the ADIR (Annual Dose of Incorporated Radioactivity, being equivalent to 0.2 mSv, resulting from homogeneous exposure of the human body to natural potassium-40 and carbon-14), as this dose equivalent is almost constant whatever the size of the individual and the geographic region.

6— The Academy of Medicine, in accordance with its statement given October 3, 2000, continues to recommend maintaining, without modification, the European directive concerning regulatory limits (to 100 mSv/5yr). To substitute dose limits of 20 mSv/yr would reduce the flexibility of the European norm, without offering any health advantage, and would harm medical radiology departments by making the development of new techniques more difficult.

# National Report Issued

On April 12, 2002, the Canadian Nuclear Safety Commission released "The Canadian National Report for the Convention on Nuclear Safety".

This publication reports on Canada's compliance with the Nuclear Safety convention since the last report in April 1999. Under the Convention signatories must hold a review meeting at lest every three years. These review meetings provide an opportunity to report on performance, to review the performance of other signatories, and to learn best practices.

The full report is available on the Commission's website: < www.nuclearsafety.gc.ca >

# Licence Fees to be Increased

Fees charged by the Canadian Nuclear Safety Commission will rise next year, with nuclear power plants bearing most of the increase. The new fee schedule is intended to bring CNSC's cost recovery up to 80% from 59% in 200 -2001. The annual fees for the CANDU 6 plants will be just over $3 million while that for Darlington will be $5.2 million.

The CNSC is holding consultations during May to determine the likely impact of the proposed fees and to seek input on alternatives that might be considered.

The proposed fee structure can be found on the CNSC website < www.nuclearsafety.gc.ca >

# Further CNSC re-organization

As noted in the previous issue of the CNS Bulletin, the Canadian Nuclear Safety Commission has gone through a significant re-organization. The "top level" structure was given in that issue as follows:

| | | |
|---|---|---|
| Operations Branch | Vice-President | Ken Pereira |
| Corporate Services Branch | Vice-President | Denys Vermette |
| Office of International Affairs | Executive Director | Ken Wagstaff |
| Office of Regulatory Affairs | Executive Director | Mike Taylor |

In early April 2002, Ken Pereira announced the following structure of the five directorates in his Branch.

| | | |
|---|---|---|
| **Operations Branch** | | |
| **Power Reactor Regulation** | Director General | Jim Blyth |
| - Bruce Division | Director | Jim Douglas |
| - Darlington Division | Director | Bev Ecroyd |
| - Gentilly 2 Division | Director | Robert Leblanc |
| - Pickering Division | Director | Peter Wigful |
| - Point Lepreau Division | Director | Chuck McDermott |
| **Nuclear Cycle and Facilities Regulation** | Director General | Cait Maloney |
| - Wastes and Geosciences Division | Director | Richard Ferch |
| - Uranium Mines & Contaminated Lands Division | Director | Rick McCabe |
| - Environmental Protection and Audit Division | Director | Patsy Thompson |
| - Research Facilities Division | Director | Barclay Howden |
| - Processing Facilities and Technical Support Division | Director | Doug Metcalfe |
| **Nuclear Substance Regulation** | Director General | Tom Viglasky |
| - Operations Inspection Division | Director | Doug McNab |
| - Technical Services Division | Director | André Régimbald |
| - Class II Facilities and Dosimetry Services Licensing Division | | (vacant) |
| - Nuclear Substance and Radiation Devices Licensing Division | Director | Bob Irwin |
| - Transportation Division | Director | Peter Nelson |
| **Assessment and Analysis** | Director General | Ian Grant |
| - Engineering Assessment Division | Director | Imtiaz Malek |
| - Human Performance Division | Director | Terence Taylor |
| - Systems Engineering Division | Director | (vacant) |
| - Organization and Management Systems Division | Director | Garry Schwarz |
| - Plant Thermalhydraulics Division | Director | Dave Newland |
| - Security and Emergency Response Division | Director | Pierre DubÈ |
| - Physics and Fuel Division | Director | Parvaiz Akhtar |
| - Personnel Certification Division | Director | Joe Cameron |
| **Operational Strategies** | Director General | Ian Grant (acting) |
| - Regulatory Strategy and Process Division | Director | Howard Neilson-Sewell |
| - Regulatory Standards and Research Division | Director | Philip Webster (A) |

The CNSC now has about 480 total staff.

# People

**Dr. Aly Aly,** formerly of the Canadian Nuclear Safety Commission, has been appointed to a newly created corporate position of "Chief Quality Officer" at Atomic Energy of Canada Limited. He took up this new role on April15, 2002.

Dr. Aly had been with the CNSC and former Atomic Energy Control Board for 17 years, most recently as Director, Research and Production Facilities Division. Before joining the AECB he spent four years at the Chalk River Laboratories of AECL. He has over thirty years of experience embracing reactor operation, research and development, development of computer codes, safety analysis, as well as licensing.

In this new position, Dr. Aly will be responsible for the development and maintenance of a Quality Management System and for ensuring the entire company meets quality standards. He will be reporting directly to the President.

**Dr. George Bereznai** has been appointed the first Dean of Dean of the School of Energy Engineering and Nuclear Science at the newly formed University of Ontario Institute of Technology, in Oshawa. UOIT is the first new government funded university in Ontario in the last 40 years. Although the new Institute has received start-up funds, the enabling legislation has not yet been passed.

For the past six years Dr. Bereznai led the Thailand HRD Project, located at Chulalongkorn University in Bangkok. That program was closed on June 30, 2001,

He reports that he is planning two degree programs to start in September 2003: one in nuclear engineering and one in radiation physics and is currently in the early stage of obtaining approval from the Ministry of Colleges and Universities.

# More problems with MAPLE

During testing of the MAPLE 1 reactor in February one of the shut-off rods failed repeatedly to poise, i.e., stuck during withdrawal. Atomic Energy of Canada Limited submitted a report on their investigation to the Canadian Nuclear Safety Commission in early April but CNSC staff reported at the Commission meeting of April18 that they were still reviewing the report.

Subsequently, one of the shut-off rods experienced a loss of hydraulic pressure. The cause was determined to have been a piston rod becoming detached from the piston head. This was corrected and 300 poise and drop tests were conducted successfully.

CNSC staff conducted a Quality Assurance audit in early April but their report was not ready for the Commission meeting of April 18.

Despite the on-going problems, CNSC staff reported that "AECL has made good progress in meeting the prerequisites for the restart of the MAPLE 1 reactor".

# Summer School on Neutron Scattering

The National Research Council at Chalk River Laboratories is pleased to announce that D. Allan Bromley, Sterling Professor of the Sciences at Yale University, will be the keynote speaker at this year's Summer School on Neutron Scattering to be held between the 16th and 21st of June.

Originally from Westmeath Ontario, Dr Bromley worked at Chalk River from 1955 to 1960. In recent years, Professor Bromley served as Yale's Dean of Engineering. He was the first Cabinet level Assistant to the President of the United States for Science and Technology and Director of the White House Office of Science and Technology Policy (1989-1993). A distinguished nuclear physicist, he is known as the father of modern heavy ion physics for his pioneering studies on the structure and dynamics of nuclei.

The summer school will provide an introduction to the techniques of neutron scattering and applications in Chemistry, Physics, Biology, Materials Sciences and Engineering. Sessions are organized with lectures in the morning and hands-on demonstration experiments with neutron spectrometers at the NRU reactor.

Financial assistance is available for participants coming from Canadian institutions. Please apply for assistance only if you require it. Applications must be received prior to May 15th to qualify.

For information on the summer school and registration forms, see the web site http://neutron.nrc.ca/school1.html .

## Obituary

**Al Dahlinger**, a member of the early small group that pioneered the Canadian nuclear power program, died in Mississauga, February 3, 2002. The following note is based on a tribute delivered by George Pon at a Memorial Service held February 8.

Al joined the Chalk River Laboratory of NRC in 1950 immediately after graduation from the University of Manitoba and joined a small group under Les Haywood on Instrumentation and Control. In the late 1950s he became the youngest Branch Head in Atomic Energy of Canada Limited.

In 1965 he moved to the Power Projects group (now Sheridan Park) as Branch Head of Instrumentation, Control and Power on the Gentilly 1 project. In 1969 he was given complete responsibility for the project.

Subsequently he was appointed head of the division dealing with instrumentation and control for all of the AECL nuclear power reactor projects. In 1974 he was appointed Vice President, Heavy Water, with an office in Ottawa. This included responsibility for the heavy water plants at Glace Bay and Port Hawkesbury in Nova Scotia and the proposed Laprade plant in Quebec. In 1980 he retuned to Toronto as Vice President, Quality Assurance, until his retirement in 1986.

To quote George Pon, *"He had sympathy, empathy, understanding and horse sense. He lived expectantly and believed confidently. For a man with such a light step he left a big footprint. His shoes will be difficult to fill. He was one of the best and brightest"*.

## Adam at IYNC

***Ed. Note:** Following is a slightly edited version of the report by Adam McLean to the CNS Council on his attendance at the International Youth in Nuclear Congress held in Daejeon, Korea, April 16 - 20, 2002*

*Adam McLean joins Han Seong Son, Adele Hollick and Alexandre Tsiboulia, at the IYNC in Daejon, Korea, holding the IYNC after winning the bid for the next IYNC meeting in Toronto in 2004.*

### Background

The International Youth In Nuclear Congress is a bi-annually held conference first held in 2000 in Bratislava, Slovakia. (Jeremy Whitlock attended that meeting.) It's motto is "Youth, Nuclear, Future" and its mission is to create an international forum and enable a network for young people in university and beginning careers in the nuclear field. Knowledge transfer is a major part of this endeavour. The Congress is organized by the International Young Generation Council - made up of YNG memberships from around the world, including our own NA (North American) YNG. (As many know, voting YNG members are limited to 35 years of age, but honorary members of more advanced age are more than welcome.)

At the second congress, held April 16-20, 2002 at Daejeon, South Korea, over 270 attendees from 39 separate countries presented over 90 technical papers. Major sponsors include Areva, BNFL/Westinghouse, the IAEA, the American Nuclear Society, the European Nuclear Society, the Korean Nuclear Society, the Russian Nuclear Society, and the Nuclear Energy Institute. Keynote speakers of the highest calibre were there and added greatly to the optimism felt by all of the Congress attendees.

### Personal Experience

When I arrived near Seoul at the brand new Incheon International Airport (completed less than one year ago), I managed to find my hotel (via bus and taxi - note that English is not very common, especially outside Seoul). The next day, I woke up early (who can sleep after a 19 hour flight and 13 time zones?) and took a grand walking tour of the city.

Although about the same physical land-size of Toronto, Seoul has a population of over 11 million. Buildings are very common, sometimes as far as the eye can see. The subway system is HUGE - 9 separate lines criss-cross throughout the city but are all very new (cellular phones work throughout them - even tiny flip-phones which EVERYONE in Korea has!) and fairly easy to follow once you get a handle on their size.

In one day, I was able to visit the entire '88 Summer Olympics area (village, stadiums, monuments), the Seoul Tower (similar to our CN Tower but about 1/2 the height), palaces, parks, the Korean War memorial, two malls, a local McDonald's, the Canadian Embassy, and other monuments, most notably to the gods of soccer (er, football) that will shine down on Korea and Japan next month :)

The next day, I traveled to the conference site in Daejeon, about two hours by bus away. I was the first to arrive at the Dormitory reserved for conference attendees ($20 CAN per night) but got settled quickly. The remainder of the IYNC executive council arrived the next day and we immediately started bag preparation, making signs directing people throughout the conference building, and preparing for attendee registration. I worked very closely with the IYNC chair, Alexandre Tsiboulia (Russia), the general local chair, Han Seong Son (Korea) and the technical program chair, Adele Hollick (UK), helping out wherever I could to watch and learn from their experience.

Both the main conference building and dormitory are located just outside the KAERI (Korean Atomic Energy Research Institute) main security gate. The grounds of KAERI are very reminiscent of Chalk River, except being on the outskirts of a city of over 1 million (Daejeon). Two hotels about 10 km away (downtown Daejeon) held many of the conference attendees not in the dormitory.

*Adam McLean in Seoul, Korea, en route to the International Youth in Nuclear Congress held in Daejon, Korea, April 16-20, 2002. (Guess which one is Adam?)*

The conference moved along very smoothly. Both the opening and closing sessions were very successful; all meals except breakfasts were sponsored (and very traditionally Korean - my chopstick skills came in very handy); and sports activities, cultural events such as pottery carving, trips to local markets and a traditional Korean Broadway show also took place. Excellent 'Knowledge Preservation Workshops', and a 'New Management Workshop' were held along with 'Y-Notes' sessions to help record and communicate nuclear ideas between the young and elder attendees.

The awards dinner was sponsored by Areva and located at a very nice restaurant, followed by music and dancing. Each congress also has an international meeting, where members of each country represented has a chance to speak on the topic of their experience at the conference, and add recommendations for the next congress. Finally, excellent technical tours gave the choice of seeing the Yonggwang NPP + a Buddhist Temple, or the Daeduk Science Complex, including the Hanaro Research Reactor, a waste immobilization facility, the Korean Aerospace Institute, the Korean Institute of Nuclear Safety, and the KSTAR Fusion Reactor now under construction there.

Canada was represented at the conference by Kiza Francis, an Intern at the CNSC in Ottawa, and myself. We both displayed our red and white proudly, handing out Canadian Flag pins to more than 100 attendees. Kiza presented a plenary talk on "The CNSC Development Program to Encourage Recruitment of Young Engineers and Scientists" and I gave a paper on "The Role of the ITER Reactor in the Development of a Fusion Power Plant". I'm happy to say we each won the awards for outstanding oral presentations given our respective sessions. We also were asked to be co-chairs of the "Economic Challenges to the Development of Nuclear Power" session, one in which extremely positive papers were presented from Romania, Korea, China (all with CANDU connections), Macedonia and Finland.

On the second-last day of the conference, I attended the IYNC executive committee dinner and presented the NA-YGN/CNS bid to host the next IYNC in Toronto in 2004. It was very well received, with unanimous acceptance by the Council and executive of the 2002 congress. During the closing session, I presented a slightly shortened version to the entire congress population, proudly wearing my Roots Canada Olympic hat.

With a pile of business card of people offering support, and a bottle of Russian Vodka in hand, I headed home, back to Seoul, Tokyo, Detroit and finally Toronto (22 hours this time!) In all, it was a wonderful experience and I thank the CNS greatly for sending me there.

## IYNC 2004 Proposal

Now, looking to the future, the executive committee of IYNC 2004 has a big job on their hands. As local chair, I have already been in touch with the entire NA-YGN executive committee as well as the existing IYNC Council and they share my enthusiasm that we can put on as good a show as Daejeon here in Toronto, with a genuinely Canadian twist. The tentative milestone schedule for the next two years is as follows:

- October, 2002 - All executive positions for IYNC2004 filled
- January, 2003 - Meeting space confirmed at U of T
- May, 2003 - Meeting in Toronto to tour site
- September, 2003 - International meeting #1 January, 2004 - International meeting #2
- May, 2004 - Congress in Toronto

If there is anyone that would like to take part, and help out in any way, please do not hesitate to let me know, or forward this message and/or the IYNC web page (especially the bid at: www.cns-snc.ca/branches/Toronto/iync/iync2004/) along to others.

I am very confident that the people are out there, and that our local nuclear community will take hold of this opportunity to encourage the youth thinking about nuclear as a career to join the industry.

# BRANCH ACTIVITIES

## Chalk River

***Michael Stephens***

Two seminars were held since the last report;

On January 31 David Torgerson, Senior Vice-President, Technology, AECL, spoke on "R&D at AECL: The Next 10 "Years".

On March 19 Bhaskar Sur, Control & Operations Technology, AECL, and Ronald Rogge and John Katsaras, both with the NRC Program for Materials Research, jointly presented a lecture on: "Life Without a Crystal: An Overview of Neutron Holography and its Potential Applications".

Two seminars are planned for May, including one linked to the unveiling of the NPD plaque.

Reports on Branch seminars are publicized in the North Renfrew Times (the weekly newspaper for the Chalk River/Deep River area) and through the Branch webpage on the CNS Internet site.

Among other activities: the Branch purchased a radiation monitor for Fellowes High School in Pembroke and made a contribution to the 2002 Renfrew County Regional Science Fair.

## New Brunswick

***Mark McIntyre***

The New Brunswick Branch was pleased to host Jerry Cuttler on January 24, 2002 at the Saint John Regional Hospital (SJRH). The topic of discussion was the effects of low dose radiation. In attendance were approximately 40 branch members, the entire class of the Saint John School of Radiation Therapy and three medical doctors from the Oncology Department at the SJRH. Jerry discussed some of the missed opportunities and slow progress of the medical community to further study the idea of treating, or even curing, cancer with low dose radiation. Jerry supported his position with a table-full of documentation that he brought with him all the way from Toronto. The question and answer period was very lively. The debate on the effects of low dose radiation continues...

The NB Branch also arranged for Jerry to do a CBC radio interview that was broadcast on the Saint John 'Information Morning' program. The radio interview had such a response from the public that one of the Oncologists from the SJRH did a follow up interview the next day.

## Ottawa

***Bob Dixon***

On March 21 Peter Calamai, science columnist for the Toronto Star (but based in Ottawa) spoke to the Branch about "A Journalist's View of the Canadian Nuclear Industry". He described the structure of a typical large newspaper and noted the several "gatekeepers", those who decide what goes into the paper. A similar structure exists at TV station. Quoting some examples of pedantic and bureaucratic press releases he emphasized the need to explain nuclear matters in a language that lay people can understand.

Unfortunately, on the night of his talk Ottawa had one of its worst spring snow storms. Nevertheless, a respectable number of stolid members braved the weather for Peter's very interesting talk.

The Branch also supported the Ottawa District Science Fair, which was held April 6, and offered a special prize. However, again this year, there were no projects related, even remotely, to nuclear energy or radiation, the broad criteria chosen. The Branch intends to send a letter to all science teachers in the area to inform them of the prize offered by the Branch with the hope that they will encourage some students to pursue a related project.

## Pickering

***Marc Paiment***

The Pickering Branch of the CNS is back in business - two seminars were held in the first quarter of 2002.

On January 30, Murray Stewart made a presentation on Canada's bid to host the Iter fusion reactor project to a standing room only crowd. Armed with a highly polished presentation (no doubt honed by repeated use!) Murray covered the past, present and future aspects of the Iter project. The crowd was left feeling cautiously optimistic of Canada's chances, knowing that while the technical and economic advantages of the Clarington bid are clear, politics will also play a major role in the final siting decision.

On March 7, Adam McLean followed up Murray's general presentation with a more technical presentation on fusion technology issues. Adam's presentation was very well received by the crowd of over 50 people who walked away armed with a greater understanding of the tremendous technological challenges facing scientists and engineers as they look to progress fusion science from the small scale experimental phase to a large scale commercial power station.

## Sheridan Park

On April 23, Dr. Tony Rockingham, Director, Air Quality and Climate Change Policy Division of the Ontario Ministry of the Environment, is scheduled to talk about *"Environmental Protection in Ontario".* Dr. Rockingham, who has a Ph.D. in Mechanical Engineering from the Imperial College of Science and Technology, London, England, will describe the new tools that are being applied to control emissions causing smog and climate change.

## Toronto

***Adam McLean***

Over 350 people attended the several events in which the Toronto Branch was involved associated with the Canadian

National Engineering Week 2002, March 2 - 10. These included talks by:

- Peter Boczar of AECL speaking on "Fuel: Still Centre of the CANDU Universe";
- Shayne Smith of Wardrop Engineering on "The ITER International Fusion Reactor"; and
- Adam McLean of the University of Toronto on "ITER and the Development of a Fusion Power Plant".

On the heels of this extremely successful period, the Toronto Branch has continued a busy schedule of events.

Local CNS members were kindly invited to attend the latest talk in the University of Toronto Chemical Engineering Distinguished Lecture series. Dr. Masahiro Kawaji gave a very informative account of his work in fluids behaviour in microgravity, an extension of his long history of involvement in the nuclear industry. Thanks to Professor Greg Evans for his dedication to the lecture series program and for inviting the CNS to take part.

The much anticipated 2002 Toronto Area Science and Technology will take place on the morning of Saturday April 20th, again at U of T's University College Last year, the CNS Toronto Branch was able to take part with both funding for the fair and judges. See our Community web page for pictures of some proud kids and more details: http://www.cns-snc.ca/branches/Toronto/community.html

This year, we're taking another big step, sponsoring both their general operations fund, and two awards of $100 each for projects relating to nuclear, energy and other high-tech topics. These will be handed out at the closing awards ceremony, and will certainly be a memorable experience for more potential future nuclear scientists and engineers.

For more information and pictures of the winners, stay tuned to the Toronto Branch web page, and the Science Fair web page at: http://www.scitechfairs.toronto.on.ca

Also coming up, CNS members have been invited by the Professional Engineers of Ontario (PEO) to a public seminar by Dr. R.L. Hemmings of Canatom NPM Inc. and former head of an ITER Conceptual Design Team in Japan. His talk, entitled "ITER - The Way to Cleaner Energy for our Planet", will take place on Tuesday May 28, 2002, 6:30 - 9:30 PM in the Council Chambers of East York Civic Centre at 850 Coxwell Ave. If you would like to attend, please inform Mr. John Glover at < gloverjc@pathcom.com > or at (416) 463-3169.

# New Members

We would like to welcome the following new members, who have joined the CNS since our last report.

Nous aimerions accueillir chaudement les nouveaux membres suivants, qui ont fait adhésion à la SNC après notre dernier rapport.

| **Name** | **Organization** |
|---|---|
| Jennifer Ilene Quirt | McMaster University |
| Mark Ferry | Ontario Power Generation - Pickering Nuclear |
| Afshin Ghaforian | RCMT |
| John F. de Grosbois | AECL |
| Abbas Habibi | RCMT |
| Keith Walter Brideau | Pt. Lepreau Nuclear Generating Station |
| Grant Russell Malkoske | MDS Nordion |
| Al Shpyth | Canadian Nuclear Association |
| Nanjappan Ardhanarisamy | AECL |
| Doug Lee | Babcock & Wilcox Canada |
| Bhisham Kumar Beri | AECL |
| Jason Michael Wight | OPG Pickering |
| Benoît Dionne | University of Florida |
| Christopher Dudley Francis | AECL |
| Garo Marcarian | AECL |
| Ela M. McDonald | AECL |
| Paul Allan Drope | AECL |
| William R. Richmond | AECL |

| **Name** | **Organization** |
|---|---|
| Jasvir Singh Bajwa | Ontario Power Generation |
| Robert Van Adel | Atomic Energy of Canada Ltd. |
| Diane Lyon Spencer | NB Power |
| Jennifer Chang | Candesco Research Corporation |
| Kathy Atkinson | AECL |
| Winston Andrada Ladores | AECL |
| Waheed Ghulam Rabbani | AECL |
| Peter Bretagne Bonfa | Bruce Power |
| Leo J. Fortin | Bruce Power |
| Richard Alan Holt | Queens University |
| Shaun K. Cotnam | AECL |
| AECL Library Services | AECL |
| Jin Jiang | University of Western Ontario |
| Lloyd Raymond Kadden | Bruce Power |
| Jason Li | |
| Lovell Paul Gilbert | Bruce Power |
| Lixuan Lu | University of Western Ontario |
| Deepak Dhar | Babcock & Wilcox Canada |
| Prabhu S. Kundurpi | Ontario Power Generation |

# CNS Honours NPD in 2002

June 4, 2002 will mark the 40th anniversary of the first electricity from nuclear power in Canada. NPD, the 20 MWe nuclear power demonstration plant and the first CANDU unit, first delivered electricity to the grid on June 4, 1962.

To mark this anniversary the Canadian Nuclear Society has chosen it as the theme of its Annual Conference in June 2002 and include a special historical plenary session. *(See the preliminary program in this issue of the* CNS Bulletin.*)*

### Historic Plaque

As well, the CNS has worked with the Ontario Heritage Foundation to have an historical roadside plaque erected near the site of the former demonstration plant at Rolphton, Ontario, about 20 km west of Deep River. An unveiling ceremony for the plaque will be held at Rolphton on **Saturday, June 1, 2002,** just prior to the Annual Conference, which will be held in Toronto, June 2 - 5, 2002.

Anyone who had anything to do with the design, construction, or operation of NPD, or who simply has an interest in Canada's nuclear heritage, is invited to attend the event. Representatives of the major corporate partners of the NPD (Atomic Energy of Canada Limited, Ontario Power Generation as the successor to Ontario Hydro, and General Electric Canada, formerly Canadian General Electric) project will be invited along with government representatives and the media.

The CNS Chalk River Branch is planning a special retrospective seminar on the subject of NPD, in the town of Deep River on Friday evening, May 31, 2002. Lorne McConnell, head of NPD Operations and later a Vice President of Ontario Hydro, is a confirmed speaker at this event.

Anyone interested in taking part in these events, having suggestions for speakers or would like to volunteer as one, should contact Jeremy Whitlock at 613-584-9723 (home) or 613-584-8811 ext 4265 (work), or send an email to whitlockj@aecl.ca.

Check the CNS website < www.cns-snc.ca > for further and updated information.



# Annual General Meeting

As has been the pattern for the past few years, the Annual General Meeting of members of the Canadian Nuclear Society will be held at the end of the first day of the Annual Conference, on Monday, June 3, at 1700 hrs (5:00 p.m.) at the Delta Chelsea Hotel, Toronto, in a room to be announced.

The AGM is the occasion for members to hear reports on the activity of the Society, to question officers, to offer suggestions, and to vote for members of the governing Council for 2002 - 2003. Members do not need to attend the Annual Conference to participate in the Annual General Meeting and no prior registration is required. Refreshments will be provided.

# 27th Student Conference

The 27th CNA / CNS Student Conference will be held on Sunday, June 2, at the Delta Chelsea Hotel, Toronto, immediately prior to the CNS Annual Conference.

The Student Conference will be arranged in two sessions, one from 8:30 a.m. to noon, the other from 12:30 p.m. to 3:00 p.m.

Members of the Society are invited to attend. Judging from last year's Student Conference, the quality of the papers will be high and the presentation professional. In fact, many adult members could learn from the manner in which the students address the challenge of this conference.

At the time of writing the room had not been assigned. Check at the Conference registration desk.

# 23rd Annual Canadian Nuclear Society Conference and 27th Annual CNS/CNA Student Conference 2002 June 2-5, Holiday Inn on King, Toronto, ON

**(Summary program as of 2002 May 01)**

**Sunday June 2**

09:00-15:00 Student Conference - Sessions S1, S2 of Student Papers

19:00-21:00 Conference Reception - Celebrating AECL's 50th Anniversary, Address by R. Van Adel, President and CEO, AECL

**Monday June 3**

**Plenary I:**
**Current Status and Future Expectations**

08:30 Welcome, *D.P. Jackson (CNS) and K. Talbot (Conference Chair)*

08:45 Nuclear Recovery and Commercial Readiness, *P.R. Charlebois (OPG)*

09:10 The First Year and the Future, *D. Hawthorne (Bruce Power)*

09:35 Possible Refurbishment of Pt. Lepreau - Update 2, *P.D. Thompson (NBP)*

10:00 Update on Gentilly-2 Refurbishment Pre-Project, *R. Pageau (Hydro-Québec)*

10:15 Break

10:45 Overseas CANDU Projects and Performance, *G. Kugler (AECL)*

11:10 Nuclear Power: The Sustainable Energy Option for India, *V.K. Chaturvedi (NPCIL, India)*

11:35 Heavy-Water Reactors: Status and Projected Development, *R. Lyon (IAEA)*

12:00 Luncheon - Guest speaker: T.B.A.

14:00 to 17:00
- Parallel Sessions: Physics I;
- Thermalhydraulics;
- Isotopes & Medical Applications;
- Operations, Maintenance and Performance

17:00 CNS Annual General Meeting

**Tuesday June 4**

08:30 to 12:00
- Parallel Sessions: Physics II; Safety I,
- Waste Management;
- Control & Instrumentation;
- Aging & Plant-Life Extension I

10:00-10:30 CNA AGM (then CNA Board Mtg.)

12:00-13:00 NAYGN Prof. Development Seminar

Plenary IIa:
The Present and the Future

13:30 Canadian Uranium in the World Market; Production at McClean Lake, *J. Rowson (COGEMA Resources Inc.)*

13:55 MAPLE Reactors for Secure Supply of Medical Isotopes, *G. Malkoske (MDS Nordion) & J.-P. Labrie (AECL)*

14:20 The Advanced CANDU Reactor (ACR) - An Update on the Next Generation CANDU Product, *D. Torgerson (AECL)*

14:45 Break

Plenary IIb:
A Look Back at Our Nuclear History

15:15 NPD, Canada's First Nuclear Power Station, *L. McConnell*

15:40 Early Development of Full-Scale Nuclear Power in Ontario, *W. Morison (MORWIL Inc.)*

16:05 The Evolution of Procurement and Supply Conditions for CANDU Fuels, *E.G. Bazeley (E.G. Bazeley & Associates)*

18:00 Reception: Cocktails and Entertainment: (Climax Jazz Band)

19:00 Awards Banquet - and more music

**Wednesday June 5**

Plenary III:
Future Challenges and Opportunities

08:30 Prototype CIRCE Plant: Industrial Demonstration of Heavy Water Production from Reformed Hydrogen Source, *D. Spagnolo (AECL)*

08:55 Risk Management in the CNSC's Regulatory Program, *T. Viglasky (CNSC)*

09:20 Update on Radioactive Waste and Spent Fuel Management in Korea, *M.-J. Song (NETEC, Korea)*

09:45 Brief Update on Waste Management Legislation and Organization, T.B.A.

10:00 Break

10:30 Current Priorities of the Canadian Nuclear Association, *W. Clarke (CNA)*

10:55 Servicing the Nuclear Industry in a Privatized, Deregulated Competitive Market - UK Experience, *K. Routledge (NNC UK)*

11:20 Panel: Opening of the Electricity Market in Ontario - Nuclear Effects. Panelists: *D. Goulding (IMO); B. Boland (OPG); A. Johnson (Bruce Power)*

12:00 Luncheon - Guest speaker: T.B.A.

14:00 to 17:00
- Parallel Sessions: Safety II;
- Aging and Plant-Life Extension II;
- Radiation Protection & Shielding;
- Management and Public Policy, The Future

BOOK REVIEW

## Unlocking the Atom

by: Hans Tammemagi and David Jackson

ISBN 0-9730040-0-2 280 pages

McMaster University Press 2002

***Ed.Note:*** *A requested independent review was not available at press time. It will be included in the next issue of the CNS Bulletin. The following is taken from the jacket of the book.*

Unlocking the Atom gives an introduction to radiation, both natural and man-made, and covers the complete nuclear spectrum including power reactors, safety, nuclear waste, medicine, uranium, fusion, industrial and research applications. this material is presented from a Canadian viewpoint, although it is placed in a global perspective. Unlocking the Atom is illustrated with nearly 80 figures and photos with profiles of a dozen Canadian nuclear pioneers. For more information or to order a copy go to website: < www.unlockingtheatom.ca >

BOOK REVIEW

## Decide the Nuclear Issues for Yourself: Nuclear need not be unclear

by: J.A.L. Robertson, M.A., F.R.S.C.

This publication by Archie Robertson, a former senior scientist at the Chalk River Laboratories of Atomic Energy of Canada Limited, is available on his website: < www.magma.ca/~jalrober > or can be accessed through the website of the Canadian Nuclear Society: < www.cns-snc.ca >.

To quote from his foreword:

"The vast majority [of the public] are vaguely uneasy about [nuclear energy], fear radiation and believe that the subject is too complex for them to understand. It is some of these average individuals that I hope to reach with this book, to show them that anyone can understand enough to form their own opinions on the issues."

"The website is divided into three parts. Part B, which discusses the issues of public concern, is the biggest. First, however, some necessary background on the basics of nuclear energy and its history is presented in Part A. Finally, Part C makes some suggestions for how readers can reach their own decisions on the issues that have been discussed."

BOOK REVIEW

## The Skule Story: *The University of Toronto Faculty of Applied Science and Engineering 1873 -2000*

by Richard White

ISBN 0-7727-6704-1

University of Toronto Press, 5201 Dufferin Street, Toronto, Ontario M3H 5T8 $30 for alumni, $40 others

Following is an extract from a review by Drew Wilson

Commissioned, as part of the celebration of the 125th anniversary of the founding of the Faculty of Applied Science and Engineering, The Skule Story required two years of research and writing before it appeared in 2000. Once again, it is strongly narrative, with an evident element of social history. But it also includes an illuminating discussion of the issues in engineering education in this country over the years since it was first offered through the universities.

The view the author takes is principally the one seen from the Faculty Office and through the eyes of the person in charge - first the principal of the School of Practical Science (SPS) and later the dean of the Faculty (FASE). His main themes are the (usually evolutionary) change within the School/Faculty, who brought the change about, and the Faculty's influence on the Ontario economy. White also describes, as appropriate for his text, the growth and development of the individual disciplines and departments within SPS/FASE. The book is divided into five chapters, each covering roughly a quarter of a century and taking between 40 and 60 pages to do so. There is a useful map of the Faculty's buildings on campus. At the end are five supplementary sections taking up a further 70 pages, including a most useful list of "Works Consulted" and an index. At the very end, to supplement the main text, there is a pull-out that shows the development of the disciplines and departments of SPS/FASE from 1878 to 2000. There are photographs every four pages or so throughout the main text - mostly of people, buildings, classrooms and student activities.

Publications available

### *Externalities and Energy Policy: the Life cycle Analysis Approach*

This 240 page document contains the proceedings of a workshop held by the OECD-NEA in November 2001 on the question of incorporating external costs into energy pricing.

### *An International Peer Review of the Yucca Mountain Project*

This 96 page report presents the results of the jointly organized NEA - IAERA international peer review by a team of ten international specialists of the "Total System Performance Assessment" of the proposed waste depository in Yucca Mountain, Nevada.

### *Improving Nuclear Regulatory Effectiveness*

This 43 page report derives from discussions of a special task group which included Jim Harvie, former director-general at the CNSC and Chuck McDermott, currently director, Point Lepreau Division, CNSC.

These publications are offered free from the Nuclear Energy Agency of the OECD and are available from their website: < www.nea.fr >

# More Bang for the Puck

*by Jeremy Whitlock*

DEEP RIVER, Ont. - Scientists are reporting the first evidence of fusion energy in the surface of a hockey rink. Unlike traditional fusion research requiring multi-billion-dollar machines, this breakthrough appears to involve nothing more complex than a Zamboni and a pair of skates.

The discovery took place in this tiny, unassuming burgh, two hours west of Ottawa. Its arena is like thousands of other small-town rinks across the country, except for one unique feature: the ice is made from heavy water.

"This stuff freezes at plus-four degrees", says the rink jockey on duty, who asked not to be named, "so it's, like, good ice." While heavy water is found in regular water at roughly one part in 7000, nobody seems to know where the 100% heavy water for the Deep River hockey rink came from.

Besides its attractive ice-making characteristics, heavy water is also important for its "deuterium" content, a common fusion fuel. The arena's connection with the energy source of the future was discovered quite by accident, however.


For years it has been known that excessive collisions with ice rinks cause people to see tiny flashes of light, an effect called Lindros-luminescence. The effect is often accompanied by a persistent ringing in the ears. What appears to be happening at the Deep River rink, however, are collisions many times more energetic than normal, and involving heavy ice. Scientists suggest that the high localized pressures are sufficient firstly to heat a microscopic layer of ice into plasma, and then to squeeze together enough deuterium nuclei in that plasma to release fusion energy.

What causes the more energetic collisions in Deep River? The answer is not clear, but may be related to the higher-than-normal number of adults playing beginner hockey in this town. "Woo-ee, do we get some spectacular falls," says the organizer of one local team, the Provocateurs, who asked not to be named. "A lot of self-inflicted, high-momentum kind of things. First we took the sparks and stuff for granted, but then it seemed a bit much, even for us. Plus the craters were a bit suspicious, not to mention annoying."

Piecing the puzzle together involved another unique feature of amateur hockey in this town: a high proportion of scientists and engineers. "Over a few beers it was all figured out," says the Provocateurs organizer, "some equipment arrived at the next game, and pretty soon we had our evidence for D-D fusion: tritium and 2.5 MeV neutrons."

The rest, as they say, is history.

"We got our goalies to hammer out the Science article," adds the team organizer,

"They don't do much anyway."

International interest in the phenomenon skyrocketed once the news was unofficially announced in the local paper. Scientists by the hundreds have flocked to this tiny town on the Ottawa River. Several made it here, while missing-persons reports remain effective for many others. The Fox TV Network has expressed an interest in the visual potential of fusion-boosted slapshots. While the NHL has yet to comment on the legality of this, Commissioners admit that current ice regulations do not specify the isotopic of the water used.

Of course, this remarkable scientific breakthrough is not without its critics, most vociferously from the anti-nuclear camp. "This is a new area of nuclear energy and they aren't telling us much," says Toady Adams of the think-tank Everything Is A Problem. "We must study its risks and pitfalls. We're asking the government to hold a full Environmental Assessment, and of course this must include an adequate amount of intervener funding."

Quirky Adnauseum, spokes-person for the Campaign to Eliminate Options, is more dismissive: "At first we wanted to know where all that heavy water came from, but they told us the Ottawa River is so deep that the heavier stuff sinks to the bottom, where it can be extracted. So we're okay there." "As for the experiment itself - we're not holding our breath. This is just more of that cold-fusion crap."

However, Adnauseum echoed the call for a full federal Environmental Assessment, and the need for intervener funding.

There is nothing but support, meanwhile, from local citizens. "This explains the boosted immune systems in kids that play on the Zamboni snowpile," says one neighbour. Officials with the local curling club plan to use heavy ice next season, and look forward to spectacular effects during their lights-out Rock n' Curl evenings.

*The author claims no responsibility for the veracity of this story, but does thank Gary Dyck for bringing it to his attention.*

# CALENDAR

## 2002

**June 1** — **NPD Historic Plaque Ceremony**
Deep River, Ontario
Contact: Dr. J. Whitlock
AECL-CRL
Tel: 613-584-8811 ext. 4265
e-mail: whitlockj@aecl.ca

**May 5 - 8** — **4th CNS International Steam Generator Conference**
Toronto, Ontario
Contact: Robert Tapping
Tel: 613-584-8811 ext 3219
e-mail: tappingr@aecl.ca

**May 14 - 16** — **Nuclear Technology 2002**
Stuttgart, Germany
e-mail: jk@inforum-gmbh.de

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

**June 2 - 5** — **23rd CNS Annual Conference**
Toronto, Ontario
Contact: CNS office
Toronto, Ontario
Tel. 416-977-7620
e-mail: cns-snc@on.aibn.com

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

**Aug. 4 - 8** — **Spectrum 2002**
Reno, Nevada
See Website:
www.ans.org/spectrum

**Aug. 11 - 16** — **International Nuclear Atlantic Conference**
Rio de Janiero, Brazil
Contact: Everton Carvalho
e-mail: everton@rio.inb.gov.br

**Sept. 4 - 6** — **World Nuclear Association 2002 Symposium**
London, UK
website: www.world-nuclear.org
e-mail: wna@world-nuclear.org

**Oct. 6 - 10** — **ANS International Topical Meeting on Probabilistic Safety Assessment**
Detroit, Michigan
See Website:
www.ners.engin.umich.edu/PSAConf

**Oct. 7 - 9** — **ENC 2002 International Nuclear Congress and Exhibition**
Lille, France
See Website:
www.enc2002.org
e-mail: enc2002@to.aey.ch

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

**Oct. 16 - 18** — **Americas Nuclear Energy Symposium**
Miami, Florida
website: www.anes2002.org

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

**Nov. 17 - 21** — **ANS Winter Meeting**
Washington, D.C.
website: www.ans.org

**?? (Fall)** — **Corrosion of Nuclear Reactor Core Components**
Toronto, Ontario
Contact: CNS Office
Tel. 416-979-7620
e-mail: cns-snc@on.aibn.com

## Twenty-Second Nuclear Simulation Symposium

# Nuclear Power in Canada: Step Into the Future

### November 03-05, 2002

### Westin Ottawa Hotel, Ottawa, Ontario, Canada

# Call for Papers

The 22nd Nuclear Simulation Symposium organised by the Canadian Nuclear Society will be held November 03-05, 2002 at the Westin Ottawa Hotel in Ottawa, Ontario, Canada in the heart of downtown.

The scope of the Symposium covers all aspects of nuclear modelling and simulation, and generally includes sessions in thermal hydraulics, reactor physics and safety analysis. The main objective of the Symposium is to provide a forum for discussion and exchange of views amongst scientist, engineers and academics working in various fields of nuclear engineering.

Papers are solicited on technical subjects relating to simulation of applications of nuclear technology. Papers on advances in the state of the art, on future developments, on novel technical approaches and on work under development are encouraged. In particular, papers are welcome in the following topics:

- System and sub-channel thermal hydraulics
- Reactor physics, including nuclear fuel management and advanced fuel cycles
- Safety analysis methods including best estimate and uncertainty analysis
- Computer code validation
- Fuel and fuel channel behaviour
- Passive safety concepts
- Advanced reactor design concepts
- Research reactors

## General Information

- Deadline for receipt of summaries: May 31, 2002
- Notification of acceptance: June 30, 2002
- Deadline for receipt of full length manuscripts: September 30, 2002

## Abstracts and Papers Information

Abstracts should be approximately 750-1200 words in length (tables and figures counted as 150 words each) and should reflect the work to be presented. They should contain not only the work that has been performed but also the results achieved. Abstracts should include an introductory statement indicating the purpose of the work and a closing statement summarizing the significant new results or basic conclusions. The author(s)'s affiliation and contact information should be properly specified. Full papers should be around 10-12 pages in length and should not exceed 15 pages total.

*Abstracts should be submitted, preferably by e-mail, in PDF format or MS Word, to the Technical Program Chair:*

Dr. Vladimir Khotylev
Canadian Nuclear Safety Commission
280 Slater, P.O.Box 1046, Station B
Ottawa, Ontario, CANADA K1P 5S9
Telephone: 613-992-4735
Fax: 613- 943-1292
E-mail: **khotylevv@cnsc-ccsn.gc.ca**

*For general conference information contact:*

Ms. D. Rouben, Canadian Nuclear Society Office
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Telephone: (416) 977- 7620
Fax: (416) 977- 8131
E-mail: **cns-snc@on.aibn.com**

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Chair of the 22nd Nuclear Simulation Symposium
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# 2001-2002 CNS Council • Conseil de la SNC

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Judy Tamm . . . . . . . . . . . . . . . . . . . . .905-823-9040
Walter Thompson . . . . . . . . . . . . . . .506-458-9552

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