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DE LA SOCIÉTÉ NUCLÉAIRE CANADIENNE

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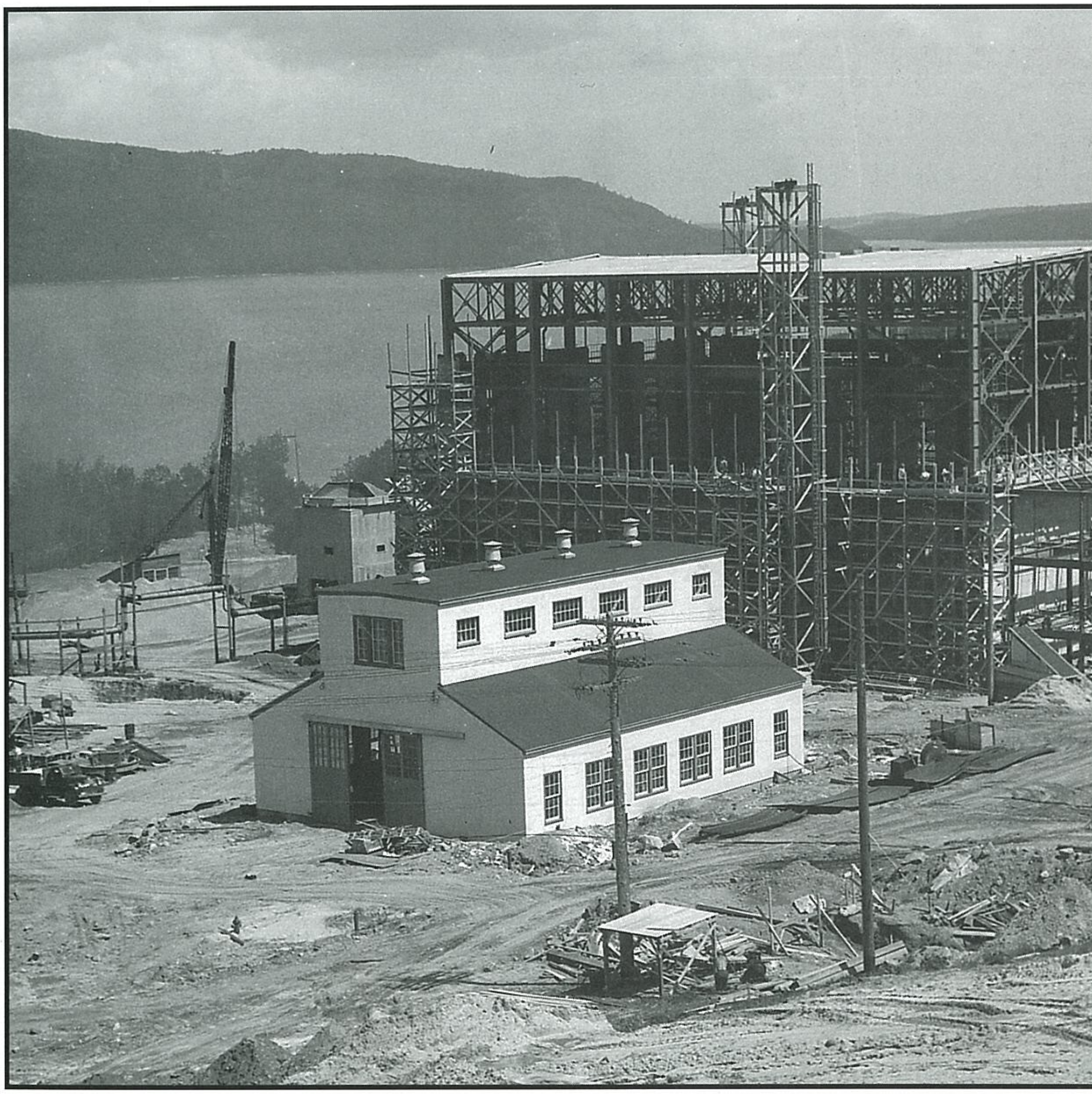

- ZEEP: The little reactor that could
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- Fuel Conference

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Cover Illustration

The cover photograph shows the ZEEP facility on June 21, 1945, with NRX under construction in the background. See article on page 3.

(Photo courtesy of AECL)

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*La SNC procure aux Canadiens intéressés à l'énergie nucléaire un forum où ilf peuvent participer à des discussions de nature technique. Pour tous renseignements concerant les inscriptions, veuillez bein entrer en contact avec le bureau de la SNC, les membres du Counseil ou les responsables locaux. La cotisation annuelle est de 60.00$**, 35.00$** pour les retaités, et 20.00$ pour les étudiants.*
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EDITORIAL

LOOKING BACK - and FORWARD

The celebrations held to mark the 50th anniversary of nuclear fission in Canada cast our thoughts back to the start-up of the ZEEP reactor in September 1945 and the exciting period it began. Although that start-up was not the beginning of the nuclear program in Canada it was a very symbolic milestone. The operation of that small reactor was the first demonstration of the remarkable work of the members of the Montreal Laboratory and the early Chalk River Project.

The contrast between the social environment and mood of those days and today is striking. There was the secrecy of the immediate post-war period compared to the almost total openness (including non-ending public inquiries) of today. The number of people involved in the nuclear program was still small and they had to contend with restricted working and living conditions. However, there was great enthusiasm and excitement. Those involved sensed they were on the threshold of a great advance in science and technology. And, they received strong political and, later as the program became known, public support.

During the drafting of a technical history over the past few years it was observed repeatedly that in the first two or so decades of our program problems were identified, analyzed, responded to, and, generally, overcome in a matter of months. Now it takes that long to create the committees to look into the situation.

We may have been our own worst enemy. By being so engrossed in the challenge of our technology we neglected to communicate with those who would use it. We allowed the picture of the bomb and the military use of nuclear technology (and of the sloppiness of the associated programs) to contaminate the public's view. And, we neglected to advertise the many benefits that evolved in nuclear medicine, industrial applications and, of course, nuclear power.

Today the term "nuclear" has sufficient negative connotations that even those involved in medical and industrial applications do not wish to be associated with "nuclear" organizations like the CNS and CNA which have become almost totally focused on nuclear power.

There is no easy remedy. The prominence of nuclear power means that the public will be won over only when they are convinced that nuclear power is safe, reliable, economical and, particularly, needed. This will be a slow process. It is essential that our existing nuclear power plants operate reliably and economically, without any significant incidents, until the need for power resumes.

At the same time we need to reach out to those involved in other applications of nuclear science and technology, especially to those in the health fields, to convince them to join forces. Otherwise, the extreme attitudes of the anti-nuclear lobby could result in the end of **all** nuclear applications.

IN THIS ISSUE

This issue presents another eclectic mixture.

Our lead article is a fascinating look back at an important step in the beginnings of the Canadian nuclear program. As well as reminding us of the importance of the start-up of the first reactor outside the USA fifty years ago, Ralph Green's paper **"ZEEP - the little reactor that could"** provides a snapshot of those early years and a glimpse of some of the pioneers who laid the foundation for the present program.

This historical picture is followed by two views of the present and future in **"A Conversation with the President of the AECB"** and **"A Conversation with Don Anderson"**. Atomic Energy Control Board president Dr. Agnes Bishop, in an interview in mid-October, offers some insights into her perspective of the current nuclear situation and of the future directions of her regulatory agency. In a conversation with associate editor Ric Fluke just before his surprise retirement, Don Anderson, former General Manager of Ontario Hydro Nuclear, provides many thought-provoking comments on the present and future of our nuclear power program.

As a change of pace there are two papers on non-power applications of nuclear technology. **"Nuclear Applications for Health"** (which is extracted from a recent publication of the International Atomic Energy Agency) gives an overview of the many uses of nuclear technology in the diagnosis and treatment of disease. **"Radiation Techniques for the Detection of Explosives"** reviews how various sources of radiation can be used in the challenging task of uncovering explosives, especially in luggage.

Then there are reports from two recent successful conferences, the **19th Simulation Symposium and the 4th International Conference on CANDU Fuel**. Accompanying the former are some **abstracts** of papers presented at the Symposium while the latter is followed by a selected paper **"AECL's Progress in Developing the DUPIC Fuel Fabrication Process"**, describing the some of the work towards the direct use of PWR fuel in CANDUs.

There is, of course, news of the Society and of other related happenings and activities.

For those who can tear themselves away from their computers, we have two **book reviews**. Unfortunately, a special **Crossword** that Keith Weaver had prepared went astray. We hope that we can run it in the next issue.

As always we thank associate editor Ric Fluke and other contributors. Your comments and suggestions are welcomed.

DEADLINE

The deadline for the next issue, which will be published about the end of January, will be **Wednesday, January 10, 1996**.

The Curse of the Linear Hypothesis

Sometimes a concept that is based on reason and has beneficial objectives can become so distorted in its application that it causes more harm than good.

Such, many argue, is the case of the linear dose-effect relationship hypothesis for radiation protection. What was once accepted as rational basis for dose limits and, in particular, for the concept of ALARA - reducing doses As Low As Reasonably Achievable - has now become, its critics contend, an albatross around the neck of the nuclear industry.

When adopted in the late 1950s by the International Commission on Radiological Protection as a basis for its recommendations on dose limits and radiation protection in general it was widely accepted. The data from the Japanese and other studies of victims of high doses of radiation all indicated a linear relationship. It was natural, and considered the appropriately cautious approach, to extend that linear relationship down to zero.

One beneficial outcome was that "acceptable" doses now had to be based on the concept of risk, since there was no "safe" level. That ushered in a long period of studies on risk - risk evaluation, risk management, risk acceptance, that continues today.

However, the hypothesis began to be applied in ways not foreseen by those who advanced it originally. Even within the nuclear community the hypothesis was used to justify large expenditures against the "common sense" judgements of many. For example, for the case of the release of carbon 14 from reactors, very large expenditures to contain the isotope were calculated to be justified because of its long half-life and the fact that, as carbon, it would invade all biological material. Theoretically, even a small release could lead to thousands or millions of deaths since the number of persons who could be exposed would be very large and, thus, so would the person-sieverts of population dose.

The same argument has been advanced against CANDU nuclear power plants (even by those in the nuclear industry but who are competitors) because of the tritium that is produced and released in miniscule quantities.

The same type of calculations have been made by critics when referring to the [theoretical] number of casualties that could or would result from an accident.

Things began to come to a head with the 1991 recommendations of the ICRP which would reduce dose limits by about a factor of five. Understandably, many in the industry screamed, to little avail since regulatory bodies like the Atomic Energy Control Board rely on reputable international organizations like the ICRP for guidance.

Others became concerned. Many scientists began looking at the growing information on the effects of low levels of radiation dose.

Dr. Bernard Cohen conducted an impressive analysis of lung cancer versus radon levels in homes throughout the USA. He examined death records from more than a thousand countries across the USA and matched them with data on ses prepared by the Environmental Protection Agency. He discovered that not only was the dose-effect relationship not linear for that situation, it was **negative !**

A group of research organizations in the USA have published, for the past four years, the BELLE Newsletter, BELLE standing for Biological Effects of Low Level Exposures. This group is not limited to radiation but has been examining the biological effects of small exposures to, or doses from, chemicals as well. For radiation and for many chemicals the contributing scientists have discovered that there is often a beneficial effect from low level exposures.

During the recent meeting of the American Nuclear society in San Francisco, Dr. Myron Pollycove gave the Roentgen Radiology Centennial Award lecture. Dr. Pollycove is professor emeritus of the University of California at San Francisco, a past president of the American College of Nuclear Physicians and a past officer of the Society of Nuclear Medicine. Since his retirement in 1991 he has been a Visiting Medical Fellow with the US Nuclear Regulatory Commission.

Dr. Pollycove spoke eloquently and convincingly about the growing evidence that shows the lack of adverse health effects from low doses of radiation and even, in some cases, beneficial effects. The evidence comes from both biological and epidemiological studies, including a number of Canadian ones. What was most shocking were his allegations, supported by others, that normally reputable bodies, such as the BEIR Committee (US National Academy of Science committee on the Biological Effects of Ionizing Radiation) had deliberately ignored such studies.

CNS president, Jerry Cuttler, has presented this argument to the president of the Atomic Energy Control Board, Dr. Agnes Bishop, urging reconsideration of proposed dose limits. Dr. Bishop, understandably, has stated that the AECB relies on the recommendations of recognized bodies such as the ICRP and will not change until they do.

Some within the radiation protection community in Canada accept the new information. Many do not. It would seem logical for the CNS to take a lead in organizing a Canadian forum. There are many Canadian researchers and practitioners who support Dr. Pollycove's position. Such a meeting will not reverse the AECB position but could be one more strong voice in the international movement for a new look at the effect of low dose of radiation.

Fred Boyd

ZEEP: The little Reactor that could

by R.E. Green & A. Okazaki

Ed. Note: *Ralph Green, a former vice-president of AECL Reasearch, gave an oral version of this paper as one of the three invited talks for the Nuclear Heritage celebrations held at Chalk River, August 4-6, 1995, to mark the 50th anniversary of ZAEEP, Canada's first nuclear reactor. He repeated the talk at AECL Sheridan Park in September.*

Co-author Al Okazaki is a former senior scientist at AECL Chalk River Laboratories.

Both worked with ZEEP in the 1950s.

Introduction

On September 5, 1945 the ZEEP reactor went critical for the first time at the Chalk River Laboratories of Atomic Energy of Canada Limited. Zeep (for Zero Energy Experimental Pile) was the first reactor to operate outside the USA. In this paper we recall some of the events that led to the construction of ZEEP, and briefly describe the role it played in the development of the Canadian Nuclear Program.

Zeep: conception to criticality

The first attempt to achieve a self-sustained nuclear chain reaction in Canada was made by George Laurence, assisted by BW. Sargent, working at NRC during the years 1940-42. Their pile consisted of sacks of uranium oxide interspersed with sacks of powdered coke. Their attempt failed mainly because of impurities in the materials they were using, although it would have been very difficult to achieve a critical assembly using natural uranium oxide and graphite, even with pure materials.

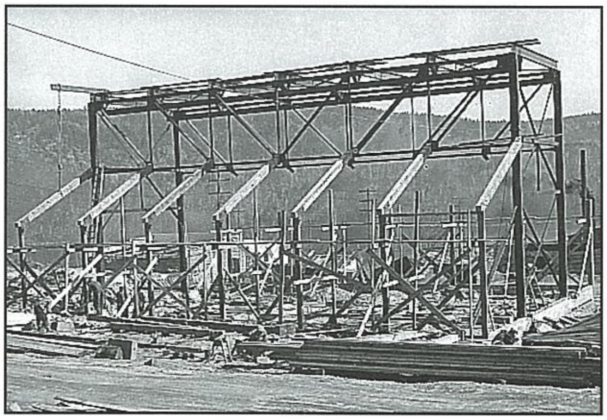
In 1942 it was decided to move the UK Nuclear Energy Program to Canada, and a joint Canada-UK laboratory was set up in Montreal in the fall of 1942. The work in Montreal, described in a pamphlet entitled *"Early years of nuclear energy research in Canada"*, by George Laurence, led to the decision, in mid-april, 1944, to build a natural uranium fuelled, heavy-water moderated reactor, what we know today as NRX. The design of NRX was based on theoretical calculations backed up by subcritical experiments in the Montreal laboratory with lattice arrangements of natural uranium metal and heavy water.

In late April, 1944 John Cockcroft came to Canada to lead the Canada-UK program. In May, 1944 Cockcroft decided it would be desirable to have some operating experience with a low-power reactor like NRX before the latter was built, and to have the capability to alter the reactor core to investigate the effect of changes to the lattice arrangement. The main reasons for building such a reactor were that it could be constructed quickly and the experience gained during the construction and operation would be valuable for NRX. It could also be used to measure some materials properties, and to test control, safety and radiation-protection equipment.

So, in July, 1944 Cockcroft asked two of his staff to look at the possibility of building a low-power reactor without seriously impeding the NRX project. In august, 1944 approval was received to proceed with the design, and Lew Kowarski, newly arrived from the UK, was asked by Cockcroft to manage the project. Charles Watson-Munro was Kowarski's second in command, and they were assisted by A.H. Allan, FW. Fenning, G.J. Fergusson, C.W. Gilbert, E.P. Hincks, H.F. Freundlich and H. Carmichael. The chief designer was George Klein from the NRC mechanical engineering division at Ottawa. He was ably assisted by Don Nazzer, also of NRC.

During the design phase there was pressure from the research staff for a reactor power of 1 kilowatt, rather than 1 watt, because this would provide neutron fluxes high enough for good cross-section measurements, for the chemists to prepare good radioisotope sources, for the engineers to study material properties and for radiation protection work to be done. However, such a power level would require more shielding to protect the operators, and would preclude the rapid rearrangement of the core to study different lattice configurations. So, the power level was kept at 1 watt.

Final approval for the construction of ZEEP was given on October 10, 1944. Construction was complete by September 4, 1945, and the reactor went critical on September 5, 1945 at 3:45 pm, only 16 months after conception and only 11 months after approval of construction. One might wonder how



ZEEP Building on April 10, 1945

ꞌong it might take to achieve that today. Of course, this was before the creation of the Atomic Energy Control Board!

The critical height of the heavy water in the ZEEP reactor was 132.8 cm, compared to the calculated level of 128 cm. This excellent prediction was made by John Stewart, a long-time AECL employee, working with George Volkoff, who later went to the university of British columbia.

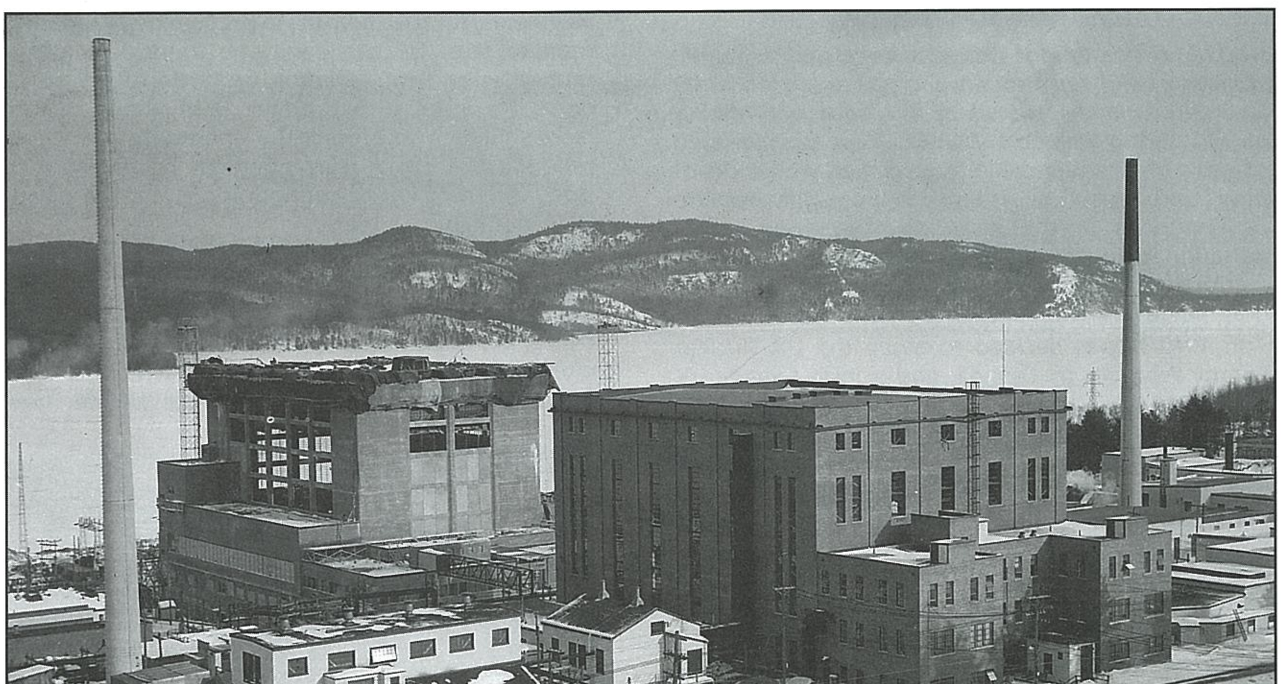
As noted above, ZEEP was the first reactor in the world to operate outside the USA, and it was a great achievement for the Canada-UK team. However, it is important to acknowledge the contribution made by the US, in providing key materials, and information from the operation of the CP-3 heavy-water research reactor at Chicago.

Early operation of ZEEP: 1945-47

Once criticality had been achieved, a busy schedule of experiments commenced, and continued up until early 1947, when ZEEP was shutdown so that its heavy water could be used in NRX. Space limitations preclude our listing all of the experiments done during this initial operating period, but the major ones were as follows:

- measurement of the buckling, or overall reactivity, of the ZEEP lattice
- measurement of the relaxation times for various subcritical and Supercritical conditions, to determine heavy-water reactor kinetics
- measurement of the temperature coefficient of reactivity
- measurement of intensities and lifetimes of delayed neutrons and delayed photoneutrons, important for reactor control
- calibration of ion chambers for the nrx control and safety systems
- measurement of the reactivity effects of various control rod configurations, including interference effecte between rods
- measurement of the neutron absorption of various nuclear materials, e.g samples of graphite and uranium for the UK reactors, and thorium for the NRX j-rod annulus, where it was planned to produce u-233
- various nuclear-physics experiments, e.g. The measurement of gamma-rays emitted during fission, and a search for the negative proton
- determination of ETA (number of neutrons emitted per neutron absorbed) for u-233
- neutron activation of various samples for radiochemical studies. One of these experiments determined the radioactivity produced in Ottawa River water, which enabled an estimate to be made of the activity to be expected in the nrx cooling water

The people involved in these first experiments were: J.G. Bayly, S.W. Breckon, A.J. Cruikshank, F.J.M. Farley, F.W. Fenning, G.J. Fergusson, K.D. George, C.W. Gilbert, H.E. Gove, M.W. Johns, I. Kowarski, B. Kinsey, D.J. Littler, B.W. Sargent, I. Siminovich, A.G. Ward, C. Watson-Munro and D.H. Wilkinson.



ZEEP in February 1954 with NRX and NRU (under construction, in background.

Since ZEEP initially had no shielding outside the graphite reflector, it had to operate at first at a fraction of a watt, to protect the operators. Later on, tanks of ordinary water were stacked around the reactor, wood was placed on top and a small room of masonite and steel blocks was built to house the operators. In this way the power could be raised to 50 watts for brief periods. During this first phase of operation zeep operated around the clock, except for Sundays, when the reactor was shut down at 7:30 am, presumably to give the staff time to get to church, or to go sailing, or play tennis!

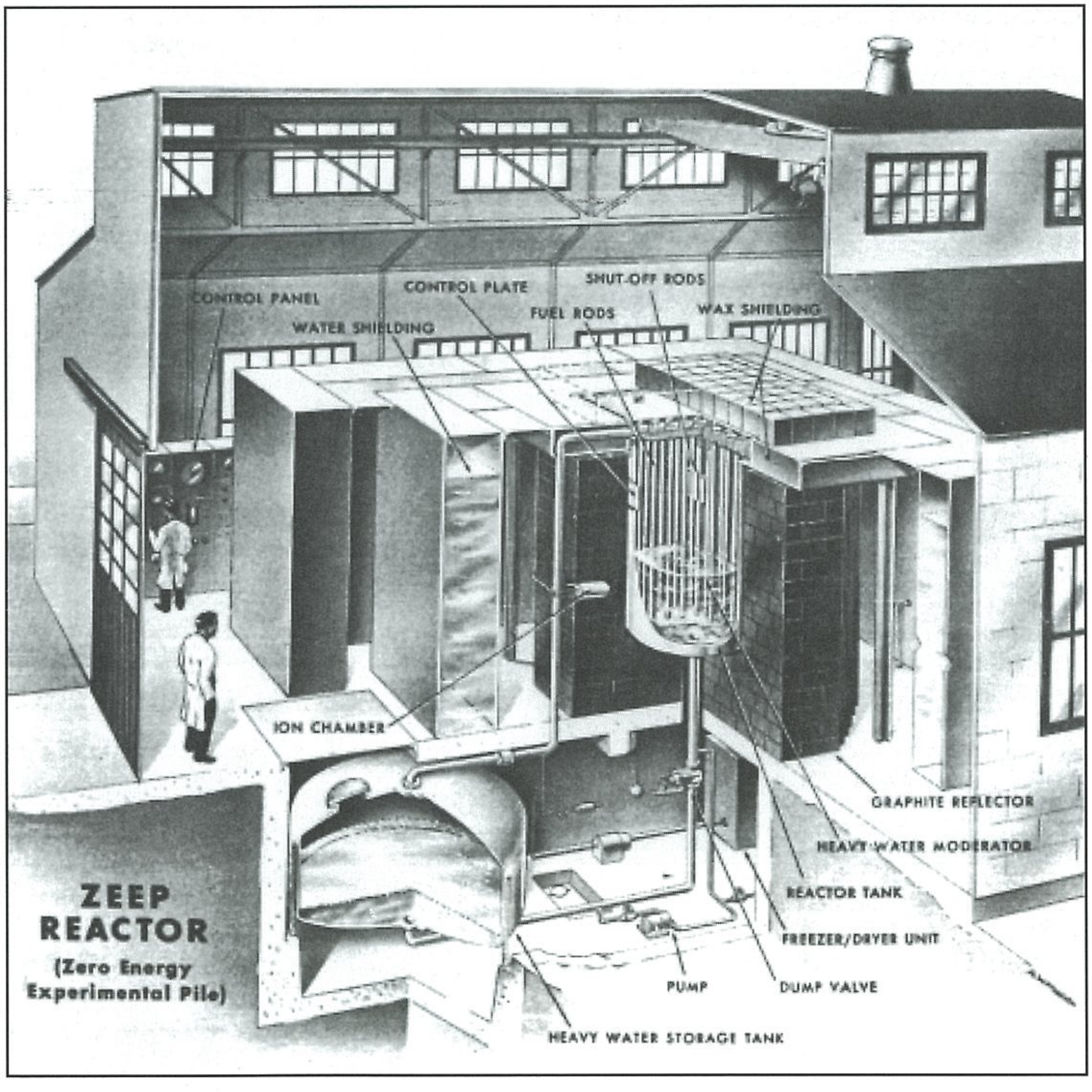
ZEEP was shut down in April, 1947, and its heavy water was transferred to NRX. Much was accomplished during this first period of operation, and much of it was relevant to the operation of NRX. However, no experiments were done to study the effect of changing the lattice arrangement, one of the original reasons for building ZEEP. Perhaps there were too many other experiments to be done, and since the ZEEP critical size had been accurately predicted, it may have been decided that the more time-consuming lattice experiments were not required at that time. These would come in the next phase of operation.

Second period of operation: 1950-56

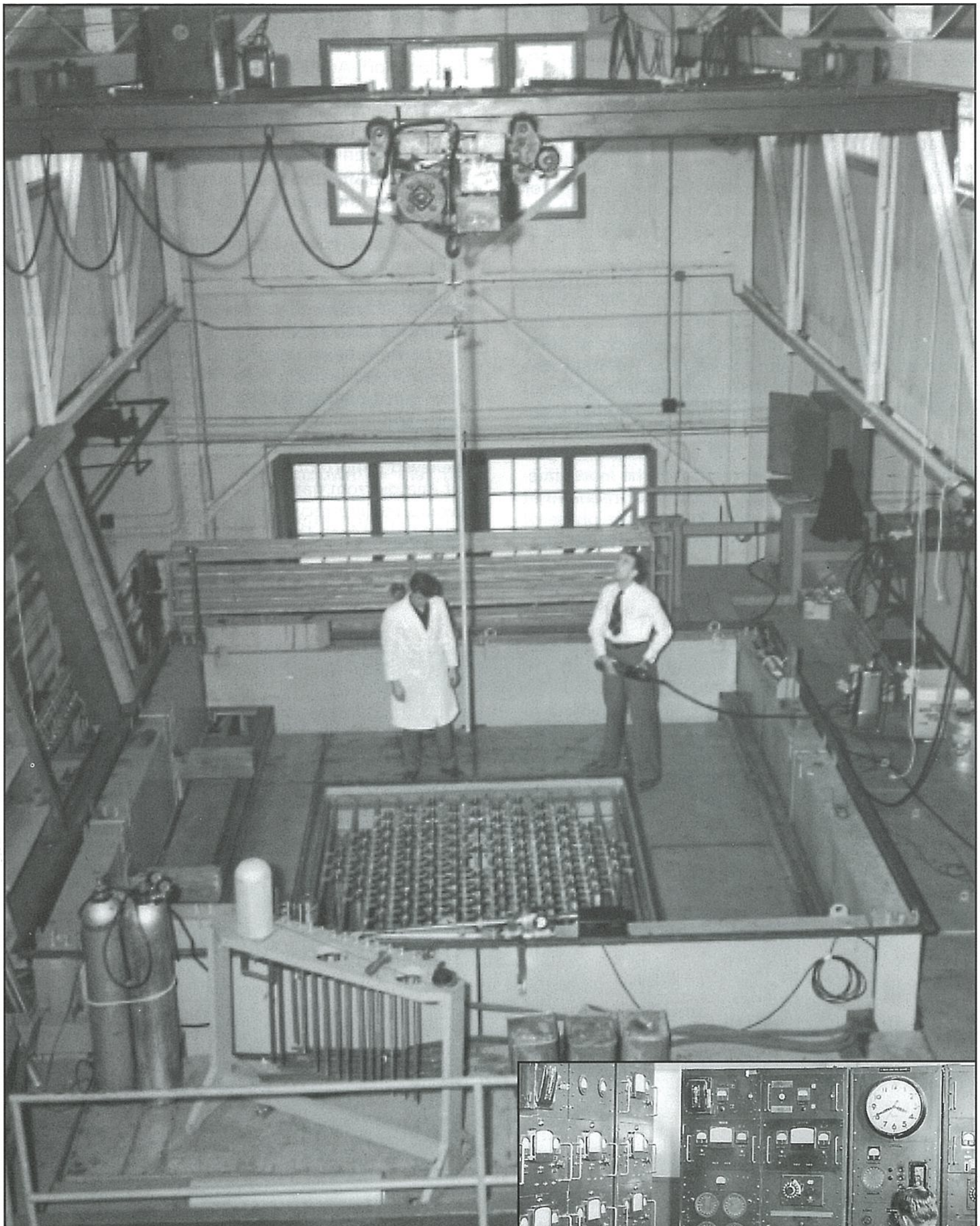
The ZEEP program started up again during the period April-August, 1950, under the leadership of A.J. Pressesky. During the shutdown new side shielding had been provided so the reactor could now operate at higher power levels, and improvements had also been made to the control system.

The focus for the experimental program now was support for the new reactor nru, then being planned. Experiments were done with different numbers of nru rods and the results were used to optimize the lattice spacing and overall core size for NRU. Other experiments were done to measure the reactivity effects of empty fuel channels and the split lattice used in NRU to provide the horizontal through tubes for neutron beam research. Other NRU-related studies involved measuring reactivity effects and neutron flux perturbations due to insertion of guide tubes and various control devices.

At this stage in our power-reactor evolution it was believed important to extract the maximum amount of energy from natural uranium fuel, and to do this would require recycling the plutonium produced in the original fuel. This led to experiments in ZEEP with



Cutaway drawing of ZEEP as it was in 1950



ABOVE:
Top view of ZEEP prior to upgrading in 1956.

RIGHT:
ZEEP control Panel prior to upgrading in 1956

close-packed lattices that might be used as a blanket around a reactor core to produce plutonium.

There was also interest in power reactor cores with fuel rods containing large amounts of uranium, so experiments were done with 3-rod clusters of ZEEP rods to investigate this concept.

In another experiment the temperature coefficient of reactivity for the ZEEP core was measured by heating the reactor to 80 degrees celsius. Measurements of the temperature coefficient of uranium were also made, using the "swing" method, in which samples of heated and unheated uranium were alternately inserted into equivalent positions in the reactor core.

Other experiments were done with PU-AL rods prepared by John Runnalls and co-workers. This type of fuel was being considered for use in NRX and NRU.

ZEEP was also used during this period by scientists from the UK to measure the properties of fuel rods to be used in a proposed UK heavy-water power reactor.

Near the end of this period lattice experiments were done with 19-rod clusters of uranium metal, similar in size to those used later in npd and douglas point. This fuel was produced before it was clear that uranium oxide would be the eventual fuel for candu reactors.

The key players during this period of operation were D.H. Allen, W. Dickerson, D.W. Hone, J.H. Moon, A. Okazaki, R.M. Pearce, L. Pease, A.J. Pressesky and D.H. Walker.

The second period of operation was now coming to a close as plans had been made to shut the reactor down for another upgrade. There were several weaknesses in the system that needed fixing.

One was that there was no way to drain heavy water from the reactor at the control desk. The reactor was normally started up by pumping heavy water into the reactor tank to a level at which the power would increase at a fixed rate. When the desired power level was reached water had to be drained from the tank to achieve operation at steady power. However, the drain valve was located at the side of the reactor, 10 to 15 feet from the control desk. So, one operator had to manipulate this valve on instructions from a colleague watching the power meter at the control desk. (It should be noted here that the scientific and technical staff were also the operating staff.)

The shielding for the top of the reactor was also primitive compared to today's standards. There were tanks of boron-loaded paraffin that could be placed on the reactor lid, for operation at high power, but since lifting these was no fun the tendency was to operate as much as possible at low power, or for short periods at higher power. Once when ZEEP was operating without the shielding in place the NRX reactor tripped due to high neutron flux in the NRX reactor hall. After that, we were asked to inform the NRX operating staff when ZEEP was going to operate.

There was also a problem with the ZEEP shutoff rods. These were attached to cables wound on drums mounted on the rod-support beams. Sometimes when these rods were dropped to shut the reactor down the cables would jump off their drums. While this wasn't a safety concern, it did delay the experimental program.

There is one anecdote from that period that readers might find interesting. To pump water into the reactor tank one had to push a button at the control desk to start the pump. However, the pump ran only for a fraction of a minute at a time, and then stopped. So an operator had to repeatedly push the button to keep the pump running. Since this was rather tedious, one operator made a block of wood that could be used to jam the pump button so the pump would run continuously. One day, a couple of researchers were on the top of the reactor inserting detectors, and an operator was at the control desk pumping up the heavy water, with the pump button jammed. Suddenly, the phone rang at the other side of the building and the operator left the control desk to answer it, leaving the pump running. The call took longer than expected and the next thing the researchers heard was the shutoff rods dropping into the reactor. The reactor had tripped on overpower. No one knows how much radiation the researchers received since they had left their film badges in their coat pockets on the floor below! However, it couldn't have been too much since one of the researchers' wives later had a healthy baby. One might deduce from this that "a little neutron flux never hurt anyone". This incident was never reported to senior management.

ZEEP was shutdown for several months at the end of 1956. A new rolling shield for the top of the reactor was installed, as well as new control and safety equipment. The latter was similar to the instrumentation to be used in nru, so once again zeep was used as a test bed.

Third period of operation: 1957-68

ZEEP started up again in the spring of 1957. The first series of experiments involved a core of 55 19-rod clusters of uranium oxide. Although the density of the oxide was lower than that used later in the power reactors, it nevertheless enabled us to obtain the first lattice physics data for uranium oxide fuel. One experiment involved heating the whole reactor to 65 degrees celsius to determine the overall temperature coefficient.

Later we acquired a full loading of 7-rod clusters of the original NPD uranium oxide fuel for another series of experiments. This fuel was in the form of 50-cm long bundles, another first for ZEEP. Tests were done with heavy water and air coolants, which gave valuable information on the reactivity effect of a loss of coolant, information that was important for the design of CANDU safety systems.

In September, 1960 the ZED-2 reactor started up, and from that point on most of the full-scale lattice experiments were done there. ZED-2 was large enough that experiments could be done with complete fuel-channel assemblies, i.e. with pressure and calandria tubes. ZED-2 has provided a wealth of information for the candu program, and is still doing so today.

However, the role of ZEEP was far from over. A hot loop was installed at the centre of the reactor and was used to measure detailed neutron-spectrum effects in candu fuel at elevated temperatures, in an attempt to more closely simulate conditions in the power reactors.

During this period a series of experiments was done to check the feasibility of determining lattice parameters by using a small number of fuel assemblies located at the centre of a large core of different assemblies. This substitution technique was of great interest since it would, if feasible, reduce the amount of new fuel required for such work in the future.

Many other valuable experiments were done in ZEEP during this final period of operation. Some of the more significant ones were:

- measurement of the reactivity of several NRU fuel assemblies, in an attempt to explain a loss of 7 mk in reactivity when new fuel was introduced in NRU. The reactivity loss was found to be due to boron in the aluminum coolant tubes
- measurement of flux peaking at the gaps between the ends of adjacent CANDU fuel bundles. The fuel engineers were concerned about fuel overheating at the bundle ends
- a comparison of the neutron absortion of samples of zircaloy, ZR-NB and ozhennite, prospective pressure-tube materials
- irradiation of sulphur capsules for the commercial products division of AECL to explore ways to enhance the production of P-32
- tests of self-powered flux detectors being developed by J.W. Hilborn
- the reactivity of douglas point type fuel bundles for the CANDU reactors in India

We are now up to the end of 1968, and from here on ZEEP was used sporadically, as all of the lattice physics work was being done in ZED-2. From this point until its final shutdown the reactor was used mainly by university students for post-graduate projects. ZEEP was shut down for good on July 27, 1970, after almost 25 years of outstanding service.

The major players in this last phase of operation were D.H. Allen, G.A. Beer, C.B. Bigham, D.S. Craig, B.G. Chidley, W. Dickerson, R.E. Green, K.J. Hohban, D.W. Hone, B.A. Maciver, A. Okazaki, R.J. Patterson, D.J. Roberts, L.P. Robertson, K.J. Serdula, P.R. Tunnicliffe, R.W. Turner, D.H. Walker and S. Yewchuck.

Other R & D programs

As noted at the outset this has been the story of ZEEP. However, lots of other things were happening in parallel with the ZEEP activities, and since ZEEP was shut down, which contributed greatly to the success of the Canadian Nuclear Program.

Experiments in the NRX, NRU, and WR-1 reactors, and work in AECL's laboratories and Canadian industry, were used to develop the key features of the CANDU reactor system, such as:

- highly successful fuel and on-power fuel-handling systems
- fuel channels, comprising the pressure and calandria tubes
- heat-transport system components
- systems chemistry and corrosion-control methods
- heavy-water production technology
- computer control and candu-specific instrumentation
- reactor safety technology
- radiation-protection equipment
- methods for the handling and disposal of both low-level and high-level nuclear waste

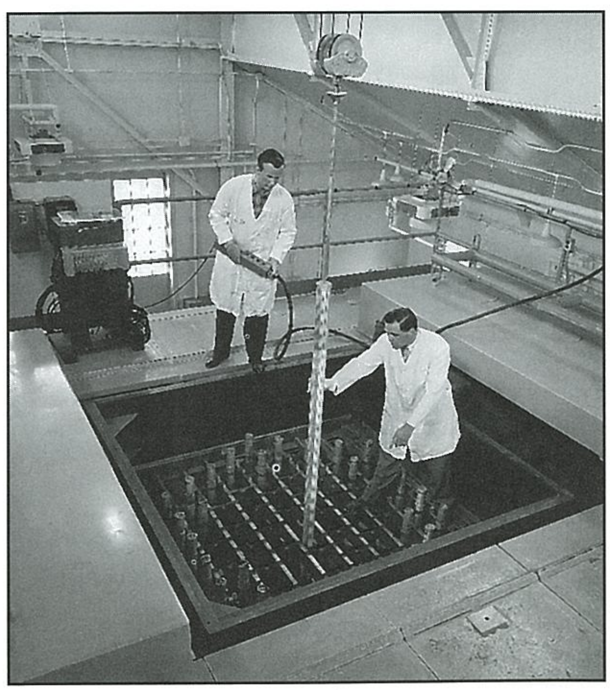
Each of these areas has a great story to tell, and these can be found in a book entitled *"Canada enters the Nuclear Age"*, the technical history of AECL as seen from its research laboratories. This book is currently in the press and should be available early in 1996.

Conclusion

In this paper we have tried to take you back in time to the early days of the canadian nuclear program, and to give you a summary of the history of ZEEP, whose 50th anniversary we are celebrating this year. We hope you will agree that while ZEEP was a small reactor, it was a very versatile one, and made a large contribution, out of all proportion to its size, to the Canadian Nuclear Program.

It represented the first self-sustained nuclear chain reaction in Canada, the first outside the USA, and launched us on the road to CANDU the best power reactor system in the world.

Therefore, we hope you will agree that ZEEP deserves the sub-title given at the outset: "the little reactor that could". Indeed, perhaps this sub-title should be expanded to "the little reactor that could, and did".



Top view of ZEEP after 1956 upgrading.

A conversation with the President of the AECB

Ed. Note: *On September 1, 1994, Dr. Agnes Bishop took on the post of President of the Atomic Energy Control Board and in that capacity serves as both the chairperson (and only full-time member) of the five-member Board and CEO of the AECB organization. She had been a (part-time) member of the Board since 1989.*

At the time of her appointment Dr. Bishop was professor and head of the Department of Paediatrics at the University of Manitoba, head of the Department of Paediatrics and Child Care at the Children's Hospital of Winnipeg and head of Paediatrics at St. Boniface Hospital in Winnipeg.

A native of Nova Scotia, Dr. Bishop obtained a B.Sc. from Acadia University and an M.D. from Dalhousie University. She is a Fellow of the Royal College of Physicians and Surgeons in Canada.

Dr. Bishop agreed to an interview for about the first anniversary of her appointment. The meeting actually took place October 11, 1995.

Dr. Agnes Bishop, President of the Atomic Energy Control Board

Managing a technical regulatory agency is not that much different, in principle, from managing a large university or hospital department, Dr. Bishop stated in response to questions about her new role as President of the AECB. As a member of the AECB Board she had become intrigued with the challenges facing the organization and decided to respond positively to the Prime Minister's invitation to take on the presidency.

Part of her first year, she commented, was spent becoming more familiar with the day-to-day operation of the AECB and with the staff, whom she described as dedicated and competent. A number of specific events (such as the incident at Pickering NGS unit 2 last December) required special attention.

Like her recent predecessors, Dr. Bishop feels it is essential to maintain and enhance the credibility of the AECB. Realizing communication is essential she has instituted a policy of holding meetings of the five-member Board at various locations where significant licensing actions were underway. This fall the Board is holding three consecutive meetings outside Ottawa, in Saskatoon, Kincardine and Port Hope. A special public session was held in Pickering last January.

About the time of her appointment the Auditor General released the report on the management audit of the AECB. (See the spring 1995 issue of the CNS Bulletin.) Dr. Bishop welcomed the report and took action immediately on assuming the presidency.

Work on a new Act, identified by the Auditor General as of high priority, was already well underway. Dr. Bishop shepherded it through final drafting and internal reviews. She now expects the new legislation to be tabled in the House of Commons this coming winter.

The new Act will require a much expanded set of regulations. She insisted, however, that this does not necessarily imply new requirements but the transferring of licence conditions (and licensing requirements) into formal regulatory format. She has instituted a major effort to prepare regulations in anticipation of the passing of the new Act. (The AECB will continue to have the authority to prepare regulations which must be approved by the Governor-in-Council.)

For nuclear facilities the new regulations will clarify what is mandatory. Dr. Bishop said she does not see the AECB becoming more prescriptive but continuing the current licensing practice of a mixture of performance oriented requirements and some prescriptive ones.

The new legislation will allow the AECB to levy significant fines which, Dr. Bishop expects will aid its enforcement activities (another area identified by the Auditor General). Also, the AECB will be able to enter into formal agreements with provincial and other agencies to have them carry out some of the licensing and inspection tasks. (This might include some aspects of the licensing of uranium mines and, perhaps, as in the USA, of radioisotopes.)

Safety will always be the primary objective of the AECB, Dr. Bishop stated, but acknowledged that even a regulatory agency must be aware of costs and benefits. These are, however, difficult to measure, she noted. There is, she commented, a need to determine what is an "acceptable risk" or, at least, a level of risk that could be considered "socially responsible".

On staffing, Dr. Bishop said that she did not expect much change from the current level of about 400 while noting there are several areas where the AECB needs to expand its efforts, such as environmental effects, human factors and radiation effects. This will require some shifting of resources and overcoming a continuing difficulty to find appropriate professionals. She noted that the AECB is aiming at 80 per cent cost recovery.

That level of staffing requires definite action to maintain effective internal communication, she commented. Noting that the informal communication that takes place in a smaller organization is no longer adequate she is taking steps to improve communication within AECB.

The AECB will continue to support international activities. Dr. Bishop had just returned from attending the General Conference of the International Atomic Energy Agency and a two-day meeting with representatives of regulatory agencies from countries with CANDU nuclear power plants. The first meeting of latter group was held in 1994. There are so many points to discuss, Dr. Bishop commented, that next year the gathering will be extended to four days.

In response to comments by the Auditor General, and reflecting her own views, Dr. Bishop has initiated an extensive, internal review of the organization. This is looking at basic objectives and the resources to achieve them. It is scheduled to be completed by next June and could lead to significant re-organization of the agency.

On the topical issue of dose limits, Dr. Bishop is very aware of the growing controversy over the linear dose-effect hypothesis which is the basis of current limits. She commented that a regulatory agency such as the AECB must be conservative. therefore she expects that the AECB will follow the recommendations of the International Commission on Radiological Protection, as it has over the years, until there is an overwhelming scientific agreement on a new dose-effect relationship. This implies that the reduction of dose limits proposed by the AECB in response to the recommendations in ICRP 60 will go ahead.

For the future, Dr. Bishop sees the passing of a new Act and the publication of the needed associated regulations as the highest priority. the likely re-organization resulting from the internal review will be a demanding task. Among technical issues Dr. bishop specifically mentioned the problems arising from the aging of Canada's nuclear power plants.

It is evident that Dr. Bishop enjoys her role as head of Canada's nuclear regulatory agency and is determined to make it an even more effective and credible organization. Canada's nuclear industry needs a good, sound regulatory body, she asserted, and should welcome her efforts to that end.

Call for Papers

17th Annual Conference of the Canadian Nuclear Society

Fredericton, News Brunswick

June 9-12, 1996

The 17th Annual Conference of the Canadian Nuclear Society will be held in Fredericton, New Brunswick from the 9th to 12th of June 1996, in conjunction with the 36th Annual Conference of the Canadian Nuclear Association.

The CNS will be running a technical program with concurrent sessions. Papers are to be presented orally. Normally 20 minutes are allotted for presentation with 5 minutes for questions.

Papers are invited on technical developments in all subjects relating to the application of nuclear

technology. Summaries of between 750 and 1200 words must be postmarked no later than **December 15, 1995**, to be considered. Four sets (original plus three copies with a summary covering sheet should be sent to:

Paul Thompson
1996 CNS Annual Conference chairman
c/o CNS New Brunswick Branch
P.O. Box 10
Lepreau, New, Brunswick
E0G 2H0
For information call: 506-659-2220 or FAX 506-659-2107

A Conversation with Don Anderson

by Ric Fluke

Ed. Note. *Don Anderson, formerly General Manager of Ontario Hydro Nuclear, surprised many with his decision to retire, effective September 30, 1995. Associate Editor Ric Fluke took Don's announcement as an opportunity to interview him on his thoughts about OHN and the Canadian nuclear industry. Following is a, reportedly, abridged version of their conversation on September.*

Don Anderson, former GM of Ontario Hydro Nuclear

Prologue

A friend and VP told me recently that the half-life of senior executives in the nuclear industry is about two years. I was taken aback by that because I could see it was true, but I only considered it to be an anomaly, a ripple in the norm, rather than a signal that serious changes would be taking place in the nuclear industry. Changes indeed!

The former era of political stability, industrial growth and technological advancement, from the first CANDU at Nuclear Power Demonstration (NPD) to the last one at Darlington, was the era which fostered the long successful VP careers of Pat Campbell, Larry Woodhead, Bill Morison, Sam and Elgin Horton, to name but a few. These engineers applied AECL's CANDU technology to build Ontario Hydro's Nuclear program. That era ended abruptly after Ontario Hydro announced its 25 year plan to build ten more CANDU reactors. [Note: never publish long term plans.]

Although the era ended abruptly, there were signs that Ontario Hydro's Nuclear Programme was in distress and also in danger of ending abruptly. A snapshot taken in 1991 reveals a very ill nuclear programme:

- Electricity rates where sky-rocketing (31% from 1991 - 1993), in part due to Darlington coming on line;
- Electricity sales were decreasing, due to the recession, demand management programmes and industrial restructuring;
- Ontario's CANDU performance was deteriorating, with record forced outages, in part due to cut-backs in preventive maintenance during the early 1980s
- The regulators were very dissatisfied with Ontario Hydro's performance, limiting license renewals to only six months;
- The newly elected NDP government cancelled all new CANDU development; and,
- We were saddled with a very large debt.

Obviously, Ontario Hydro was not providing the public, governments, investors and users with the confidence needed to demonstrate that it could manage a large nuclear program. But today's snap-shot reveals a much different situation:

- Electricity rates are stable and are committed to be so until at least year 2000;
- Sales were up dramatically in 1993/1994, and continue to grow gradually;
- Ontario's CANDU performance is back on track, setting new world records for continuous production (Pickering Unit 7 and Bruce Unit 8 now hold first and third place world records);
- The regulators have granted two year license renewals recently, and OHN and the AECB have mended their relationship; and,
- Progress has been made to reduce costs and help ease the burden of debt.

Furthermore, the Ontario Energy Board, which has often "bashed" Hydro in the past, made these statements in their August 1994 report:

"The restructuring of Hydro's organisation, financial affairs, corporate objectives and priorities is a solid step in the right direction."

"The Board is impressed by the progress OHN has made in resolving its technical problems and is encouraged by its latest operating and financial performance.

This is such a significant turn-around in Ontario Hydro's Nuclear program that it came as a surprise when Don Anderson announced his retirement effective September 30, 1995. So on September 25, I decided to ask Don if he knew anything about this remarkable turn-around, and indeed, if he had anything to do with it.

Here is Don's reply:

Ric, you left out the worst piece of bad news in your 1991 snap-shot. We had a Darlington plant that cost $14 billion that didn't work. There were headlines in the Globe and Mail weekly talking about Ontario Hydro's "Canary Wharf". That was probably one of the most desperate times we went through. And today, on the flip side of your comparison, the Darlington plant is performing unbelievably well! Its four units are approaching 94% Capacity Factor. This plant generates electricity at less than 0.9 cents/kwh. If that isn't a significant turn-around, then what is? Your description of the situation and the turn-around is quite apt. When we took a look at the situation and went to the root causes of what was going wrong at Hydro, I think one of the things that convinced Maurice Strong to go the way we did was driven by the fact that we had done the same thing in the Engineering and Construction organisation the year before. The old Design and Construction Branch, when I took over as Vice President in late 1990, was obviously geared for an era that no longer existed. We had to change. When we restructured Design and Construction into ENCON, we created strategic business units. This was the model that was used for the New Ontario Hydro. Although I don't always agree with Maurice Strong, my view continues to be that he was the right guy in the right place at the right time - for us, for the electricity consumers and for our shareholder, the Government of Ontario. I believe everyone in Ontario Hydro owes him a debt of gratitude for that.

You mentioned revenues and debt reduction in your snap-shot. What you didn't mention was that Ontario Hydro Nuclear generated $400 million net income in 1994, and paid down $900 million of its debt - that's not deficit, that's paying down the debt, unlike governments. The year [1994] would have ended perfectly, and I would have had a wonderful Christmas, except for what happened on the 10th of December at Pickering. That event was most unfortunate and it was the first indicator that there was some unfinished business to be done out there.

"Peer Reviews are the best way . . . to achieve world class performance."

On the whole, 1994 was a remarkable year. There was a lot of turmoil in the company. People were being relocated into new positions, and virtually a whole new management team was brought in. You might have expected terrible results. It takes a long time to turn the Queen Elizabeth around, but we did it in 1994 and got those very much improved results. I am very pleased with that. It's a testimony to all the 9300 people who work for Ontario Hydro Nuclear.

So, Ric, I would say that your snap-shot in your opening statement has the situation fairly well defined. I would simply say that there is still a large piece of unfinished business: Peer Review. Experiencing a Peer Review is not something to look forward to, but it gives a most incisive look at operations and maintenance. It doesn't just look to see if you are meeting regulatory compliance requirements; it looks at the things that are going on in the plant as a precursor to what may occur down the road. It's a painful tool, but extremely powerful. Peer Reviews are conducted regularly in the US by the Institute of Nuclear Power Operations (INPO), and I have become increasingly convinced that Peer Reviews are the best way to make sure that we achieve world class performance. But we do have some way to go.

Q: Don, before OHN was formed, the Chairman's Task Force on Change made several recommendations for the New Ontario Hydro. Clearly, the ENCON model had a significant influence, but were the recommendations implemented as intended by the Task Force?

Not fully.

It was largely right the first time through, using the "80/20" rule. When you get 80% of it right the first time, it should be pretty good. However, the 20% became more and more of a problem. I have four examples.

First, it was very clear in the original Task Force recommendations that parts of the Research Division [Ontario Hydro Technologies] that were exclusively devoted to support the nuclear business should have been made part of OHN, but it never happened. In my view, this is unfinished business.

Second, and this has hurt us quite badly, we did not decentralise the Corporate and Public Affairs function. The relationships between the nuclear plant and its local community are so important that if you don't get the organisational structure right, if you somehow have head office deciding and doing the talking with the local mayors and reeves in the area, then you can get distortions and problems developing. This too is unfinished business, in my view.

Third, we did not move immediately in Ontario Hydro to what I would call the "Holding Company" model. We are now finally moving to that model. As we speak, a team is examining its full implications.

Q: What would a Holding Company would look like in this context?

A Holding Company owns all its parts, but it gives a high degree of latitude to each of the business units to, for example, negotiate their own collective agreement, do their own tactical planning, human resource planning, but all within the ambit of an overall strategic direction, and of course the corporate holding company is the banker. That is where I thought we should go, with strategic business units that would be, as you said, self sufficient and independent within an overall corporate strategic direction. It's just taking a little longer to get to that.

The forth example of a Task Force recommendation that was not implemented was my doing. They said to shut down the entire Bruce Heavy Water Plant immediately, but I refused to do that. We set up a team and worked very hard to achieve two things which I am very proud of the team for: first, we made a major sale to Korea; second, we shut down half the line and made operations more cost effective and competitive in the world market. The BHWP has no more sales to OHN. The day it has no sales overseas is the day it stops running. So I have no regrets about not implementing that Task Force recommendation, so far, but we better make another sale soon.

Q: It was a terrible blow to everyone when all eight units at Bruce had to be derated to 60% of full power, when a safety problem was discovered. Can you tell us how that decision was made?

As part of the safety analysis of the consequences of a major loss of coolant accident, a new problem was discovered. When the safety analysis was presented to me, I called a meeting that day with the then head of nuclear operations and the two Bruce station managers. After a brief meeting, and we were all quite upset, we derated all Bruce units to 60%.

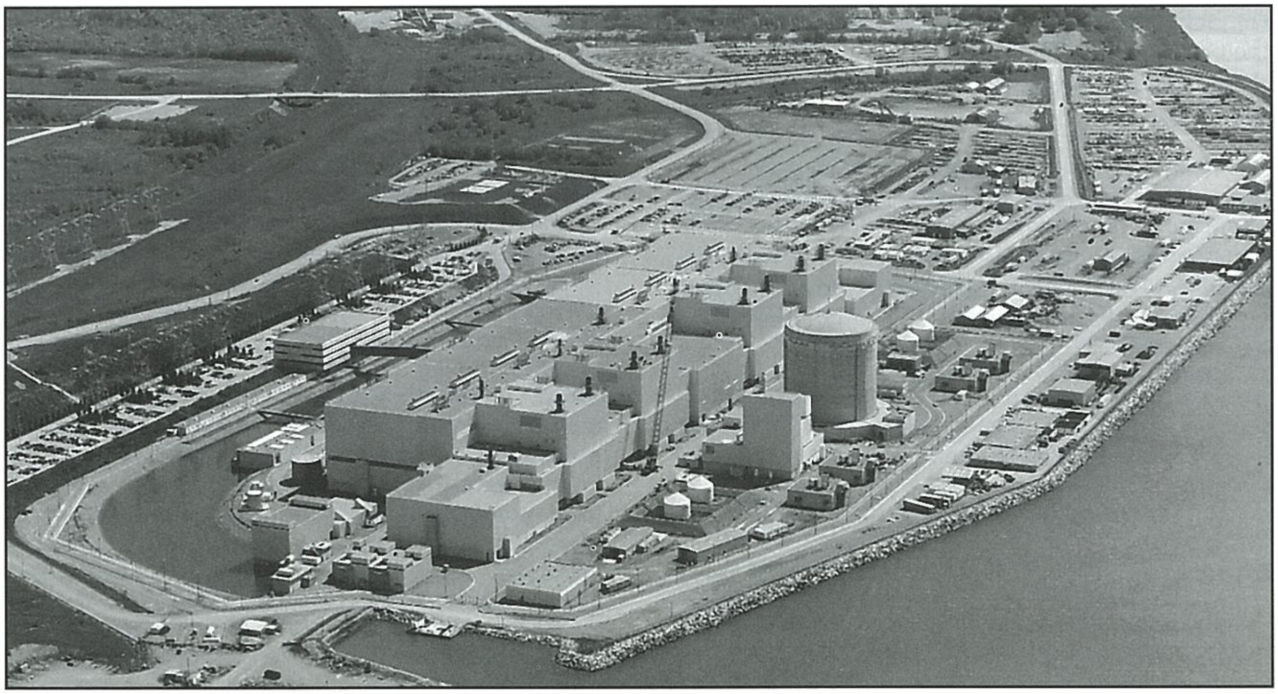
"The AECB does not give us enough credit."

You know, the AECB doesn't give us enough credit sometimes - the papers said "AECB Forces Hydro To Derate 8 Units" which was not the case at all! However, recall your opening statement about our relationship with the AECB. We have mended that relationship. I am really proud of the people who worked to produce the AECB/OHN Interface Manual. It has made life easier, although it isn't perfect yet. The AECB continues to act as if they are the only ones who make us do responsible things and I have had to remind them that it was Hydro that derated the eight units at Bruce; it was Hydro that shut down four units at Pickering after we had that loss of coolant on December 10, 1994. There are many cases of us making conservative safety decisions. We don't tell them about that often enough.

Bad news though that was, derating the eight units was the right thing to do. We learned a couple of other things. We now have Bruce B back up to 90% full power, and Bruce A up to 75%. Do you realise that the Bruce B plant has the lowest DAFOR (Derating Adjusted Forced Outage Rate) of any of our nuclear units? You might think that with the units derated that it costs us a lot of money, but at 90%, because they run farther away from their trip set-points, they run much better. A forced outage costs a lot of money. Since the forced outage rates are much lower, we got quite a lot back from the deratings. I am willing to predict that you will never see Bruce B go back to 100%, although they may obtain a licence for it. Bruce B runs extremely well in the 90-96% range. It's quiet, the pipes don't vibrate, you're not pushing things too hard and the plant runs well. If that leads to a much better DAFOR, then maybe you would not want to push it flat out to 100%.

Q: Although the technical solution to the Bruce derating problem, making the bundle longer, is very simple, the real root of the problem was that the pressure tubes had crept a little longer than they were designed to, and the safety implications of operating outside the designer's parameters were not fully understood. One of the root causes of the problem was failure to take a multi-disciplinary approach to design and safety analysis. There existed an error which was not detected by the process. How did this influence your policy making when you rolled out the new OHN?

One of the direct outcomes is the OHN Quality Assurance Programme. This is one of our high priorities with significant expenditures to introduce



Aerial view of Darlington NGS.

Quality Assurance into our tools for nuclear safety analysis. This may have caught the problem if it had been in place earlier. Remember that it only exists on the 900's. We don't have the problem at Pickering. There's no question that we got caught out on it. I fully accept that.

I would just like to add one more point in rolling out the new OHN. I strongly believe that engineering should be at site. The engineering manager who knows his station best and has the design authority for the site is in the best position to catch these kind of things. One of the drivers for creating OHN with its differentiated businesses between the stations is simply that no two of our stations are the same. They have wide differences in ages and there are significant differences in design. These parameters lead you to want to have a full engineering capability focused on that particular plant. Although some people didn't like moving to Bruce, overall, I have heard nothing but satisfaction that there has been an integration of engineering and operation at the stations.

"Engineering should be at the site."

Q: Despite some bad luck at Pickering's Unit 2 Reactor, the teething problems at Darlington, and the Bruce derating, in my opinion, OHN has clearly demonstrated that now it can manage a large nuclear programme efficiently, effectively and safely. It can turn things around, it can manage crises, it can improve performance and keep costs down. You have turned distress into success. Why are you retiring now?

You know in your heart when it is time. I'm not the kind ofperson who stays around after the music stops. This last thirty months has been one heck of a trial, and I have put an awful lot of my life on hold. It was putting too much of a strain on me. It is time. I'm looking forward to retirement. I'm going to miss the people here, though.

The nuclear programme is very important. I'll be watching.

Q: What are the next big jobs for OHN?

There are four big jobs, or pieces of unfinished business:

1. OHN has got to have all its plants undergo Peer Review by the year 2000, and improve the operation and maintenance to "A" rating using INPO standards.
2. OHN has got to land another big heavy water order.
3. OHN has got to get the financing to re-tube Bruce Unit 2.
4. OHN needs to win, against world competition, the MOX Plutonium Disposal Programme.

Q: How would you compare OHN to other large nuclear utilities such as TVA or the UK's Nuclear Electric?

Nuclear Electric and TVA have many different technologies within them. Nuclear Electric has AGRs, MAGNOX and one PWR. TVA, what few they have running, have PWRs and BWRs. OHN has only CANDU. OHN generates 70% of the province's electricity. Nuclear Electric has just got up to 26% in the UK and Wales, TVA is less than 20% of the north eastern US. Our electricity prices are the lowest of the three utilities you mentioned.

One significant difference is that we have, more technically advanced and better trained people, giving us the most potential for up-side gains. Our plants are not producing as much as they are capable of. We are still at 76% capacity factor but we could get that up to 85%.

"We have more technically advanced and better trained people."

However, Nuclear Electric has a distinct advantage, in my opinion, because it has a better corporate culture. The reason they were able to turn their nuclear programme around is the following. And get ready for this! When Mrs.†Thatcher broke up the old CEGB, she took all the nuclear assets and put them in one separate entity, which they thought was the trash can. However, that was just enough to galvanise the people, giving them a tremendous advantage; what I call a "Pure Play", that is, a single focus on nuclear, nuclear, and nuclear. Their Board of Directors is nuclear. They include prominent Ph.D's, engineers and scientists. Their finance people are there just to finance nuclear. They don't have to worry about sustainable development. They have perfect focus on Nuclear Electric.

Q: Do you think that OHN should operate more like an electric generating company, like Nuclear Electric, rather than as a line of business in Ontario Hydro?

Absolutely! There's more to it than that. I think you are alluding to the concept of Nuclear Electric Canada, which I can come back to. But the whole concept of it is premised on the fact that the vertically integrated electric utility, a monopoly position, will not survive in a market place where deregulation is coming over the boarders. What will happen is the utility, as a vertically integrated entity, will break up and then you will have generation, transmission, retail, distribution and so on. Eventually, when those entities establish, you will see individual entities start to merger, grow, accumulate, and become a larger nuclear entity, or a larger hydraulic entity, and that's what I mean by a Pure Play.

OHN is too big for Ontario Hydro. It's too dominant a part - the asset base, the number of people - and it carries routinely 70% of the generation. Within the geographic boarders of Ontario, that's a lot of eggs in one basket! But if you consider for a moment that OHN's total 14,500 MWe of nuclear capacity only represents 11% of the north east power block, suddenly you say "Whoa! That means that if there is open access, if there is free competition, free flow of energy, then suddenly nuclear is no longer a problem. It's a benefit! It's a solution."

Now this is nothing to do with privatisation, and

I'm not urging that to happen. I'm just recognising that OHN has a few more steps down the road. We started with ENCON, then we restructured Hydro. We have to go to the next step, the Holding Company, and then we have to let the separate entities of the holding company go off and do their own thing. Hydro would still probably be the majority owner.

Q: If OHN was a separate entity, and you talked about mergers, would it make sense to merge with a gas company to build a gas generator at Bruce in return for a percentage of sales to pay for re-tubing?

Absolutely and categorically no! Now I understand the concept that was studied, but it was in a different context. There is a bigger picture here, which is to create Nuclear Electric Canada which would have the financial resources to pay for re-tubing Bruce A.

I say no because I am very emphatic about Pure Play. Financial investors don't like to buy conglomerates. They love Pure Plays. They love Bell Canada stock because they know it is in one business only. The nuclear business is a high technology science industry, and it is not like the other generating businesses because it is not just the converter of raw materials to electricity.

"The nuclear business is a precursor to the way other high technology companies will have to operate in the 21st century."

More importantly, I think the nuclear business is the precursor to the way many other high technology industries will have to operate in the 21st century. We are the only industry that has completely captured all of our waste emissions. We are the only industry that has done full scale probabilistic risk analysis. There is far greater probability than one in a million that a Hydro dam will let go on the Ottawa River and wipe out part of Capital Hill. All those things lead you to realise that the nuclear industry is very different. It's a precursor for what the petrochemical industry or any industry dealing with hazardous substances in the 21st century will probably have to do as well. And we will be able to flog our services. Maurice Strong talks about sustainable development; we are the only industry that can claim full possession of 98% of all our waste since we started the business. Compare that to gas or coal or petrochemicals!

Q: We are talking about Nuclear Electric Canada, but what role do you see for OHN when most nuclear development is off-shore?

The concept is described in, "Strategic Considerations Concerning the Proposed Merger Between Ontario Hydro Nuclear and Atomic Energy of Canada". That report considers the whole gamut of things that are needed to be considered if such a thing should go ahead. The key point made is that there are two concomitant visions for this enterprise: first, this enterprise will be the dominant supplier of low cost electricity into the north east power pool; second, we will be a competitive supplier of CANDU reactors world wide. These two visions may seem unrelated but in reality you can't have one without the other. You can't continue to be the dominant supplier in the nuclear industry if the CANDU industry withers and dies. The export business can not survive without a large entity that's generating lots of cash to pay the large risk investments, to market the feedback from the operating plants, and the necessary operator training, the simulator and so on. It's the nuclear business and you need both parts for success.

Q: Are you going to apply for President of Nuclear Electric Canada?

No comment.

Q: Do you wish to make any closing remarks to your friends and readers of the CNS Bulletin?

I wish the CNS success. I think it is a good thing for Canada. I hope your chapters thrive and prosper and I support having a chapter at each of our stations. It's nice that Hydro has rejoined the CNA, something which I take some pride and satisfaction in, and we are also a member of the Uranium Institute.

The biggest remaining battle for the nuclear industry in my view is not the technology battle, nor is it the licensing battle. We have a good technology and we have a capable regulator which has integrity. And I want to be quoted on that. The battle is going to be overcoming the biases of the investment and business community about the viability of nuclear. Not that I am advocating privatisation, but we need some investment. We would like to get some private sector investment for Bruce and I think we can get it.

There has been such a long history where the nuclear business was associated with Ontario Hydro and Ontario Hydro was nuclear and the two were intertwined. I think it is important that some distance open up between the two. For focus. For business effectiveness. I won't comment on the direction of privatisation because I don't have a strong view on it. But I do know that there has been a most remarkable turn-around, which gives me a lot of satisfaction.

Last year, a financial company was brought in to look at ways to finance Ontario Hydro, bringing in more equity and helping government get off the debt. They came in here with the unwavering belief that nuclear was a "basket case". When they finished, their report said that the nuclear business is a good investment. Quite aside from whether anybody wants to invest, if it ever does happen, when you have the confidence of investors such that they want to get at you, it means that your business has got some shine and polish and I'm pleased about that.

Q: One final question, which is on everyone's mind, why is it that all of Maurice Strong's papers and speeches end on page 30, even when they appear to be only six or ten pages in total?

People delivering esoteric views sometimes get carried away with their enthusiasm. And that's all I'm going to say about that.

Nuclear applications for health

A look at health-related nuclear applications benefitting people today

by Alfrecio Cuaron

Ed. Note: *Although most CNS members are associated with the CANDU nuclear power program they recognize that there are many other applications of nuclear technology. As a small contribution towards a better understanding of these other uses we intend to publish, from time to time, articles dealing with some of the non-power applications of nuclear energy. The following is extracted from a longer paper in a recent issue of the IAEA Bulletin, the quarterly journal of the International Atomic Energy Agency. The IAEA Bulletin is available without charge to a limited number of readers. Those interested should contact the IAEA Division of Public Information, P.O. Box 100, A-1400, Vienna, Austria.*

Just before the turn of the 20th century, the discoveries of X-rays, in 1895, and of radioactivity, in 1896, opened up whole new worlds of science. For the medical community, the world has been changing ever since, in some countries far more rapidly than in others.

Over the past 100 years, the X-ray has become as familiar to most people as the dentist's chair. As we move into the next century, greater attention is being placed upon less known but more far-reaching radiation technologies and nuclear applications that today's physicians are able to use for earlier diagnosis and treatment of serious illness.

This article, in question-and-answer format, explains the differences between the various types of nuclear applications for human health and looks at the evolution of the IAEA's related activities.

Nuclear applications: What they are

What are nuclear applications for human health? Fundamentally, they are applications that either take advantage of nuclear radiation's ionizing power or of the specific properties of a particular radionuclide. The first type of applications is used to destroy diseased tissues, as in radiation therapy of cancer. The second type generally is used to gain information useful in medical diagnosis, as in nuclear medicine studies. Some of these applications represent the oldest and most humane applications of nuclear energy. They are also the most widely used nuclear techniques throughout the world.

What is radiation therapy? Radiation therapy uses highly intense ionizing radiation centered on tumours for purposes of destroying all traces of malignant tissues. At present, it is estimated that 10 million new cancer cases occur every year, most of them in developing countries. More than 60% of all cancer patients require some kind of radiation therapy as part of their treatment. Although a high percentage of cancer patients are treated with surgery alone, the use of radiation therapy and chemotherapy in combined treatment approaches is becoming frequent for curative purposes.

Is radiation therapy a new medical application? Not at all. It started nearly a century ago —in 1896— by using X-rays and it was known as roentgentherapy, in recognition of German physicist W. C. Roentgen, who discovered X rays in 1895. Beginning in 1903, it was gradually replaced by curietherapy, in honour of French scientist Marie Curie. Technically speaking, this was the first practical application of nuclear energy. It used radium sources in close contact with the tumours. Its use lasted for nearly half a century, until artificial radionuclides with superior nuclear and radiobiological characteristics were produced in cyclotrons and nuclear reactors.

Today's radiation oncologists have a choice of different approaches depending on the clinical needs of particular patients:

Brachytherapy, which can be used by applying beta particle sources in close contact with the tumour, as in the case of cancer of the uterine cervix and other cavities or surfaces, and

Teletherapy, where a gamma radiation source is positioned at a certain distance from the tumour, as in the case of deep-seated cancers.

In most industrialized countries and in quite a few developing ones, electron accelerators, in stead of radiation sources, are also used, often with better results. In addition, new techniques are emerging which are increasingly complex and expensive, but safer and more accurate. These techniques rely upon the use of proton accelerators, neutron irradiators, boron-neutron capture, and heavy-ion accelerators.

Tracer techniques and nuclear medicine

What is meant by "tracer methodology"? Thousands of years ago, the Chinese used pieces of coloured cork to trace the water currents in the Yang-Tse river. A few millennia later, the Egyptians improved the method by using massive amounts of water-soluble dyes to trace the currents in the Nile river. At present, a few molecules of radioactive water are needed to follow radioactivity and trace either the water currents in a river, a lake or a sea — or to trace water metabolism in a living organism.

Dr. Cuaron is Director of the Division of Human Health in the IAEA Department of Research and Isotopes.

When did tracer methodology become applicable to biomedical sciences? In 1932, Blumgart used a natural radioisotope of bismuth as a tracer of blood flow. By detecting its radioactivity in different regions of the body, he was able to measure with great accuracy the corresponding blood circulation times from the site of its intravenous injection. It was the first experiment on human physiology ever performed by using the radiotracer principle.

A few years later, some chemists started using other radionuclides to trace the continuous buildup and breakdown of specific organic molecules, giving birth to modem biochemistry. Knowledge of the different metabolic cycles occurring in a living organism could not be possible without the isotopic tracer principle. Only stable and radioactive isotopes can label the atoms to follow the pathways of a given atom from one molecule to others in the intricate biochemical crossroads.

How does nuclear medicine take advantage of the radiotracer principle? Nuclear medicine is based on the use of minute amounts of radioactive molecules of known biological behaviour to trace specific functions and biochemical processes. These tracers or "radiopharmaceuticals" can be thought of as guided molecular probes. If they are administered to the patient (in-vivo) or added to a tissue sample in a test tube (in-vitro), the hundred million molecular probes search through the body or the sample. They do so until they encounter recognition sites in the targeted cells where their solubility, charge, and shape lead them to be selectively bound to a cell component, to be concentrated by a specific tissue, or to be excreted by a given organ.

How can this information be of diagnostic value? These molecular probes can be tracked by external detectors and measured by their emitted radiation as they move in blood and concentrate in specific sites, providing functional and biochemical quantitative data. This information is usually given by a gamma camera in the form of planar or bidimensional images. These images show the spatial distribution of the radiotracer in the body, reflecting the quality and the regional distribution of a given biochemical or functional process. A method known as single photon emission tomography (SPET) shows the same distribution but in bidimensional images of slices of the body. The most advanced system is called positron emission tomography (PET). It provides images obtained through the use of molecular probes labeled with positron emitters produced in a cyclotron. Its use allows the analysis of the most delicate biochemical processes of life, including the interactions between radioactive neurotransmitters and neuroreceptors within the brain. It thus provides unique images of the biochemical foundation of diseases previously believed to be of "mental" origin (dementia, schizophrenia, depression, paranoia) or just "degenerative" (Parkinson's disease).

In any case, a unique feature of nuclear medicine imaging is that it is able to resolve the diverse functions in a given organ by using different radiotracers. In the case of the heart, for instance, it is possible to investigate fourteen of its functions, including biochemical and metabolic processes in its different structures.

Is nuclear medicine just a sophisticated variation of clinical radiology? Not at all. Although both are based on the use of ionizing radiation, they are directed at two different medical specialties:

Clinical radiology started in November 1895, shortly after the discovery of X-rays by Roentgen. For the first time, physicians were able to explore the structure of the internal organs of their patients without surgery, but rather through the shadows they produced on a photographic plate. The intensity of these shadows are dependent on the density of the tissues. The result is an image with information about the size, shape, position and density of the different organs. In other words, they are anatomical images. In the process, however, a wide area of the patient's body is exposed for a very short time to a very intense ionizing radiation, which is not nuclear in origin. Although certainly important, anatomy is limited to the study of structures, which are only altered in the very late stages of disease.

Nuclear medicine, on the other hand, started nearly half a century after radiology when artificial radionuclides became available through the use of cyclotrons and nuclear reactors. It evolved naturally from the principle of the tracer methodology to explore living molecular behaviour. Nuclear medicine goes far beyond anatomy into the realms of physiology, biochemistry, and molecular biology.

Do these differences between radiology and nuclear medicine have any implication in medical diagnosis? Each provides different medical indications. Radiology is used to detect the structural effects of disease while nuclear medicine is used for studying its biochemical and functional consequences. Radiology is vital for the successful treatment of a bone fracture whereas nuclear medicine would play a minor role, if any. Their relative values need to be seen in the context of the natural history of disease, which usually begins with a biochemical disturbance at the molecular level in a region of a given organ or system. With time, the regional or global function of the organ is affected, but the first structural alterations are only evident in very late stages. For instance, nuclear medicine is able to detect the first biochemical signs produced by bone metastases from breast and prostatic cancers six to twelve months before the structural changes are evident in a radiographic image of the skeleton. In this particular case, nuclear imaging is vital for the patient.

The major advantage of nuclear medicine is that it is not organ-oriented, as radiology, but problem-oriented. Nuclear medicine does not just provide new tests for old diseases. It defines clinical problems in terms of regional biochemistry and physiology and uses these measurements to help solve the problems. Biochemical and functional characterization of disease provide a strong basis not only for diagnosis but also for prognosis and treatment, whether it be drug therapy, surgery, radiation therapy, or some combination of them.

An example can be found in breast cancer. It may be well diagnosed by radiological mammography which may indicate a serious prognosis and the need for surgery and radiation therapy. But if a nuclear image shows the ability of the tumour to concentrate radioactive estrogens, it is a demonstration that the tumour has estrogen receptors, and this can be suc- cess fully treated with drugs. The finding changes not only the prognosis but avoids traumatic treat ment. This does not mean that nuclear medicine excludes radiology. Both have complementary roles. In this case, mammography is diagnostic but nuclear medi- cine defines the best treatment.

Safety and sensitivity

Is the internal administration of radionuclides safe for patients? In nuclear medicine, radionuclides are especially selected and have short half-lives. The radioactivity in the dose is just enough to be detect- ed by the sensitive instruments of nuclear medicine. Although the radionuclide remains in the body for a relatively long period when compared with the extremely short exposure time during an X-ray study, nuclear medicine exposes patients to lower radiation doses than clinical radiology where radiation intensi- ty is fundamentally high.

On the other hand, the chemical amounts of radio- tracers are so small that they cannot induce pharma- cological effects or alter physiological parameters. Neither are they able to produce toxic effects. These special features allow nuclear medicine procedures to be performed in pregnant women and in newborn babies as well as to be periodically repeated either to monitor the evolution of disease or the effects of treatment.

What is in-vitro testing in nuclear medicine? These tests are the simplest and cheapest in nuclear medi- cine. They are performed in a laboratory with very simple instrumentation, where hundreds of samples can be simultaneously processed in just a few hours. As in other clinical laboratory tests, they are per- formed in test tubes on biological samples (blood or other tissues) so they do not expose the patient to ionizing radiation. The most common are radioim- munoassays (RIA) and immunoradiometric assays (IRMA), which combine the unique specificity of immunological processes with the unique sensitivity of tests based on radioactivity.

These procedures have increased the sensitivity of biochemical measurements by a factor of one million, from micrograms (0.001 mg) to picograms (0.000,000,001 mg), allowing the discovery of unsus- pected hormonal production. They are practically used to detect and measure the minute amounts of any immunogenic substance of medical interest. Among these are hormones, enzymes, proteins, med- ical and hard drugs, as well as substances specifically produced and secreted by certain tumours, the so- called tumour markers.

In-vitro testing also includes the use of radioactive DNA probes or genetic markers. They are used to identify specific bits of DNA present in the genetic material of the cells. These bits can be further amplified or copied by the polymerase chain reaction method so that there is enough material to test even the sample containing the tiny amount of DNA of a single cell. Genetic fingerprinting, as it is popularly known, is of special value in the detection of com- municable diseases such as malaria, lepra, leishmani- asis, and schistosomiasis, as well as inherited diseases such as cystic fibrosis, haemophilia, and thallazaemia. It is also of value in parental identification, in foren- sic medicine, and in criminalistics, anthropology, and paleontology.

Are the therapeutic applications of nuclear medicine different from those of radiotherapy? Radiation therapy uses radiation beams from exter- nal sources to destroy malignant tissues. Therapeutic nuclear medicine seeks the specific, physiological concentration of orally or intravenously administered beta emitting radionuclides with enough radioactivi- ty to specifically destroy targeted tissue. In this case, the molecular probes are transformed into molecular "guided missiles" of great accuracy. If the binding site of the radioactive molecular missile is a cancerous tumour, the aim is the specific and total destruction of malignant tissues with a highly radioactive dose, with nearly no effects on surrounding normal cells. Lower therapeutic doses of radioactivity are used when the aim is to partially ablate over-active non- malignant tissues to restore normal chemistry and function in specific organs. Such is the case in the ad- ministration of iodine-131 to destroy hyperactive thy- roid tissue in the treatment of hyper thyroidism, as well as of phosphorus-32 to destroy hyperactive bone marrow overproducing red blood cells. Doses of iodine-131 ten times higher are needed to destroy the metastases of a thyroid cancer.

In a similar way, bone-seeking radionuclides are used to palliate pain in patients with bone metas- tases from breast or prostatic cancers. A new chapter under investigation is radioimmunotherapy. This is based on the use of specific radioactive monoclonal antibodies as "magic" guided missiles to destroy spe- cific types of cancer and their metastases—such as melanoma, lymphoma, and cancers of the colon, ovary, and liver — without undue irradiation to normal sur rounding tissues.

Are the costs of nuclear medicine competitive with those of radiology and other clinical imaging modalities? Nuclear medicine is not inexpensive, but the overall costs are competitive.

Generally speaking, the cost of equipment for nuclear medicine is on par with those of radiology and below those of advanced imaging systems, such as magnetic resonance imaging. Operating costs of nuclear medicine, however, are higher than those in radiology. This stems from the need to have a con- stant supply of radionuclides and radiopharmaceuti- cals which, used or not, decay with time. In terms of human resources, a radiological department needs a core staff of radiologists, technologists, and an expert in medical physics. The requirements for nuclear medicine are broader and multidisciplinary in character, encompassing nuclear physicians, technologists, radiopharmacists, biomedical engineers, and experts in medical physics and informatics.

Nuclear medicine may seem expensive, but when well applied it can actually reduce costs of health care. Decision-making under conditions of uncertainty is what makes health care expensive. Increased certainty at the earliest stages of disease results in better patient care and lower costs. Precisely this is the highest value of nuclear medicine: an early diagnosis leads to opportune prescription of the optimal treatment, and eliminates the danger of complications. It further reduces the costs for drugs, for more complex, expensive, and traumatic diagnostic modalities, and for hospital beds. It can also shorten the period of recovery for patients, and their time away from work.

Other radiation applications for health

Are there other health-related applications of irradiation? Irradiation is an efficient method of bacteriological sterilization. Many medical products, such as surgical dressings, sutures, catheters, and syringes, cannot be subjected to sterilization by steam or dry heat because they incorporate heat-sensitive materials such as plastic bases. Sterilization by ethylene oxide gas or other chemicals may introduce undesirable residues which are hazardous to health. For such products, sterilization by gamma rays from cobalt-60 has proven to be highly effective and low in cost. Tissues for graft implants in humans, such as bone, nerve, fascia, dura, heart valves, and chorion dressings for burns, also have been successfully sterilized by gamma radiation. They thus have found more use in clinical practice in many developing countries.

Other health-related applications of irradiation have been successfully promoted by the Joint Division of Nuclear Techniques in Food and Agriculture of the IAEA and Food and Agriculture Organization (FAO). Food irradiation, for example, can kill viable organisms and specific, non-spore forming, pathogenic micro organisms such as salmonella, thus eliminating many health risks in food. Another important application is in sexual sterilization of insects in eradication campaigns of pests threatening human health, such as the New World Screw worm and the tsetse fly.

What about nutrition and health-related environmental problems? The tracer principle has been fundamental in the study of all processes involved in human nutrition. The use of stable isotopes of hydrogen, carbon, nitrogen, and oxygen is completely safe to the person being studied because they are non-radioactive. Nuclear analytical techniques also have been used to provide information on the bio availability and dietary intakes of different elements through the normal human diet in various countries of the world, providing important new data useful for setting dietary guidelines.

Nuclear techniques and the tracer principle are fundamental as well in the study of environ mental pollution, which affects the health and well-being of millions of people. The fact that radioactive and non-radioactive isotopes can be detected in very small amounts and that their path can be traced, make them ideal tools for tracing pollutants, be it in air, water, or soil. Non-radioactive isotopes can be measured accurately by nuclear methods, such as activation analysis or X-ray fluorescence. Other nuclear methods such as electron beam radiation also can be employed successfully to remove gaseous pollutants, including obnoxious gases such as sulphur dioxide or nitrogen oxide emitted from coal-fired power stations.

What is the role of radiation dosimetry in human health? Accurate doses are of utmost importance for all radiation applications. For therapeutic applications, it can be a matter of life and death. A dosage lower than intended may be insufficient for treatment and may increase radioresistence in the malignant tissues; if higher, it may produce severe complications.

In modem radiation oncology, it has been stressed that accuracy, or at least repeatability, in the delivery of the dose should be within 5%. For this purpose, 70 Secondary Standard Dosimetry Laboratories (SSDLs) have been established by the IAEA and WHO in developing countries.

Much higher doses of radiation are used for some industrial applications, such as sterilization of medical products and food irradiation. Newly developed techniques are being used through the SSDLs for the assurance of the prescribed dose.

Evolving to meet the challenges

Over the past decade, the IAEA's programs in support of nuclear applications for human health have evolved to address new realities. The move is reflected in the organization structure, as well as in more sharply focused projects. In August 1993, the Division of Life Sciences disappeared from the organizational chart of the 8 IAEA. In its place emerged a new name, the Division of Human Health, whose staff are grouped into four sections—nuclear medicine; applied radiation biology and radiotherapy; dosimetry; and nutritional and health-related environmental studies.

Why the change of title? The old title be came inappropriate and misleading because its sub-programs no longer related to animal and vegetal biology, areas covered under the former Division of Life Sciences. These sub-programs have fallen fully within the scope of the Joint IAEA/FAO Division. Furthermore, the new title would have the added advantage of helping potential counterparts — mostly from medical institutes — to identify the Division's objectives with their own. This evolutionary change better enables the IAEA to keep pace with progress and to mold the IAEA's medium term strategies concerning nuclear applications for human health.

Radiation Techniques for Detection of Explosives

by Esam M.A. Hussein

Introduction

The detection of explosive material in airport baggage requires a device that can detect a small amount of explosives with a high success rate and low positive false alarm rate in a short time. The device should be able to handle carry on as well as checked baggage and should provide indications that are independent of the geometric configuration of the material.

A chemical explosive is a compound or mixture which can rapidly decompose, releasing substantial amount of heat and gas. Most chemical explosives are organic compounds or mixture of compounds. The four most common elements of an explosive are: hydrogen, carbon, nitrogen and oxygen. Hydrogen and carbon are the fuel elements, oxygen is simply the oxidizer; while nitrogen serves as a bonding agent that attaches itself to the elements of the molecule. Plastic explosives, such as C4 and Semtex, are of a particular concern; because of their stable, malleable and pliable nature which makes them easy to conceal. They also have a very low vapour pressure, which makes them difficult to detect using conventional vapour-phase analyzers.

The mass density of an explosive compound is relatively high. Also, explosives have high nitrogen and oxygen densities. Most detection techniques exploit the nitrogen-rich nature of explosives. Although few materials have such a high nitrogen density, some plastics, clothing materials and narcotics have also high nitrogen content. In order to distinguish such innocuous materials from explosives, one needs to detect the presence of other elements, particularly oxygen. The measurement of high oxygen density in the inspected object, together with a high nitrogen density, provides a strong indication that the object contains an explosive material. This is the minimum requirement for unambiguous determination of the presence of explosives. An additional measurement will decrease the degree of ambiguity and increase the reliability of the system.

A number of radiation-based techniques have been developed, or are being considered for the detection of explosives. This paper reviews some of these techniques, based on the type and mode of interaction of the radiation employed.

X-Ray Methods

Since x-ray radiographic scanners have been in use for many years in airport security, their utilization for detecting explosives is very tempting. Radiography depends on measuring the attenuation coefficient of materials. These coefficients are highly dependent on the atomic number, Z, of the atom, and increase with Z. X-rays are, therefore, best suited for detecting electron-rich materials, metals in particular. Direct use of x-rays for detecting explosives, which have elements with low Z values, is therefore not very effective. However, attempts have been made to enhance the capability of x-ray radiography so that it can provide some indication of the presence of explosives.

X-ray attenuation in organic materials (low Z) is mainly governed by Compton scattering, while the photoelectric effect is important in high Z inorganic materials. However, the significance of the latter effect diminishes rapidly as the x-ray energy increases. Metals can, therefore, be recognized by a sharp decrease in attenuation as the x-ray energy is switched to a higher energy; is while the change in attenuation organic materials is not significantly affected. Based on this premise, detection systems that employ multi-energetic x-ray machines have been developed (the so-called E-scan systems). Such systems cannot, however, provide a definite identification of explosives, although they can alert against the presence of unusually dense organic material in the inspected object.

Systems employing a combination of x-ray transmission and backscattering are also being promoted. These systems rely on the fact that light elements Compton-scatter photons but do not remove a sufficient amount of photons (neither by scattering nor by photoelectric scattering) to significantly affect the transmission signal. Heavy elements cause both a large amount of scattering and photoelectric absorption. The ratio of the transmitted to backscattered signal accentuates therefore the presence of light elements. Backscattering is used in such techniques because of its convenience. In order to obtain a spatial image, well collimated pencil beams are required. It should be emphasized here that the transmission/scattering technique distinguishes only light elements from heavy elements. This is not sufficient to uniquely identify explosives.

A more ambitious approach is to adopt computer assisted tomography (CT), commonly used for medical diagnosis. CT systems can provide a two-dimensional distribution of the x-ray attenuation coefficient in a section of the object. These attenuation coefficients, also called CT numbers, are not directly related to the electron density, but empirical formulations can be utilized to provide such relationship.

Other Photon-Based Methods

A number of techniques employing high energy photons have been considered. A technique taking advantage of the resonant absorption of gamma rays

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by the nitrogen nucleus is promoted by some groups. The concept is to produce, using a proton accelerator, a beam of gamma rays which has an energy corresponding to the resonance absorption energy for nitrogen. This resonance energy in nitrogen is about 23 MeV and the resonance cross section is about 120 mb. The detected gamma signal, after passing through a luggage containing an explosive material, will then drop significantly due to the nitrogen preferential absorption of this resonant gamma rays. The method can therefore provide a definite detection of the amount of nitrogen, without activating the material. However, oxygen has a photon resonance energy which is not very different from nitrogen, making it difficult to distinguish between nitrogen and oxygen.

Photoneutron techniques are also been considered. A nitrogen-14 nuclei, if subjected to high energy gamma rays (11 MeV or more), produces a neutron and a nitrogen-13 nucleus. The latter is a short-lived isotope, 10 minute half-life, which decays to carbon-13 while emitting a positron. The positron is subsequently annihilated by combining with an electron, producing two 511 keV gamma rays. These two photons can be detected in coincidence, providing a definite identification of the presence of nitrogen in the inspected object. It is however simpler to detect the emitted neutron to identify the presence of nitrogen-13.

High energy (more than 30 MeV) photons can also be used to transmute nitrogen-14 into nitrogen-12. This is a very short-lived isotope, 11 ms half-life, which decays by positron emission. The detection of the corresponding annihilation radiation can then be used for detecting nitrogen. Both the nitrogen-13 and nitrogen-12 reactions have very low cross sections, about 2 and 0.1 mb, respectively. Carbon-12 and oxygen-16, exposed to high energy photons result also in the production of positron emitters. The distinction between nitrogen and oxygen may therefore prove to be difficult. Also, boron-12 may be produced as nitrogen is exposed to high energy photons (more than 50 MeV). Boron-12 has a half life of 20 ms and decays by emitting a high energy electron. The bremsstrahlung radiation emitted by the electrons can be used to identify the unique presence of nitrogen.

All the above mentioned photon techniques require an accelerator to generate the high-energy photons. The production of these photons has to be a high rate, to make up for the low cross section of the interactions.

Fast-Neutron Activation

Neutron activation analysis has been used for many years for material assaying. The neutron source is usually a nuclear reactor. The gamma radiation released from the radioactive nuclide has energies which are characteristic of the parent element. For airport use, an appropriate neutron source, rather than a reactor, needs to be found. Non-reactor sources can generally be classified as radioisotope-based or accelerator-based. All commercially available radioisotopic sources emit fast neutrons. Accelerator-based neutron generators also produce also fast neutrons. Fast neutrons are therefore natural candidates for use in detection techniques.

Accelerators utilizing deuterium particles impinging on a tritiated target have been in existence for many years. Portable machines are becoming increasingly available at a reasonable cost. Such machines produce 14 MeV neutrons, which can be used to activate the inspected material, producing characteristic prompt gamma rays. The following reactions occur for the two most common elements in explosives, nitrogen and oxygen, (where the asterisk refers to an excited nucleus):

N-14 + neutron (14 MeV) → N-14* + neutron (8.9 MeV)

N-14* → N-14 + gamma (5.1 MeV)

and

O-16 + neutron (14 MeV) → O-16 + neutron (7.9 MeV)

O-16* → O-16 + gamma (6.1 MeV)

The above reactions are the most probable reactions, with a cross section of 430 and 474 mb, respectively. The reactions occur almost instantaneously, as the half-lives of the excited nuclei are in the order of picoseconds or less. The neutron-oxygen reaction also produces some lower energy gamma rays.

By monitoring the presence and intensity of the above two characteristic gamma rays, one can identify the two basic elements in explosive material. Fast neutron activation can also provide imaging information; using some form of the single photon emission imaging techniques used in medical applications. Alternatively, scanning collimated pulsed neutron beam can be used to provide a two-dimensional image of the luggage.

Another fast-neutron technique is the associated alpha-particle method. The deuterium-tritium reaction produces, in addition to the 14 MeV neutron, an alpha particle possessing a 3 MeV energy. The direction and timing of this alpha particle can be used to determine the spatial position of the emitted neutron. The characteristic gamma ray measured in coincidence with the source alpha particle define the direction of the emitted neutron. Three-dimensional element-maps can then be constructed.

Luggage materials, particularly metallic items, exposed to an intense field of fast neutrons may be activated, producing some relatively long-lived isotopes. Neutron generators are not known to be very robust and require continuous maintenance. Moreover, a significant amount of shielding will be required to provide protection against neutrons and associated gamma rays. In spite of these drawbacks, fast neutron activation is a very promising technique, as it enables simultaneous detection of the two main elements in an explosive material, nitrogen and oxygen.

Thermal-Neutron Activation

The use of thermal neutron activation (TNA) has been promoted as an effective explosive detection method. Thermal neutron activation of nitrogen is governed by the following neutron capture reaction:

N-14 + neutron (thermal) → N-15 *

N-15 * → N-15 + gamma (10.8 MeV)

The resulting gamma energy is the highest gamma ray energy produced from a nuclear reaction. The cross section for this reaction is about 66 mb. This is about an order of magnitude lower than the nitrogen activation cross section at 14 MeV. The cross sections for the analogous reaction with oxygen is much lower than that for nitrogen, thus making it difficult to detect oxygen. TNA is therefore a technique for nitrogen detection. The amount of nitrogen can be determined from the intensity of the gamma ray. The use of a set of gamma detectors surrounding the luggage can be used to provide some information on the spatial distribution of nitrogen.

TNA may also lead to the activation of other material in the luggage. Most of this radioactivity will however be short lived and would rapidly decay. In available TNA airport systems, thermal neutrons are generated by slowing down fast neutrons produced by the spontaneous fission of a few micrograms of californium-252. However, the technique does not, and cannot, make efficient use of source neutrons. Most of the original source neutrons are lost in the moderation process, while the slowed-down neutrons have a very low probability of activating nitrogen (due to the small cross section). This inefficient use of neutrons leads to the requirement of a large source activity and corresponding amount of shielding. The result is a bulky and heavy device. Being a nitrogen-only technique, TNA can result in a high rate of false detection.

Fast-Neutron Transmission

Fast neutron transmission can also be used to determine the elemental composition of an object. The method takes advantage of the fact that neutron total cross-sections for some elements possess a strong and characteristic energy dependence. In particular, nitrogen has a characteristic drop in the cross section at about 2.4 MeV, while the oxygen cross section exhibits strong resonances from about 1.9 to 1.4 MeV.

This fact was used in one technique that relies on the use of a wide energy beam, generated, for example, by a deuterium-beryllium reaction in an accelerator. The beam is then moderated to enhance the production of low energy neutrons. Thus, the concentration of elements in the path of a neutron beam can be determined from the energy spectrum of the transmitted neutrons. The neutron energy in this technique is determined by measuring the time of flight of the neutrons. The timing information is obtained by generating neutrons in a pulse mode and utilizing the timing signals provided by the deuteron pulse and the photomultiplier of a liquid scintillator neutron detector.

A simplified form of this technique, employing isotopic neutron source and commercially available detectors has been recently developed by the author and coworkers. The method relies on the use of pattern recognition techniques to identify the characteristic variations in the spectrum of transmitted fast neutrons introduced by explosive materials.

Since the fast-neutron transmission technique does not rely on activating the material, it requires neutron sources of modest intensity. This makes such a method particularly attractive.

Neutron Elastic Scattering

The elastic scattering cross section of fast neutrons is large for low mass number nuclei. At 14 MeV, the elastic cross sections for nitrogen and oxygen are about 900 and 1000 mb, respectively. These cross sections are much higher than those of any of the activation cross sections reported earlier. Neutron sources of lower strength can therefor be utilized, or alternatively the exposure time can be reduced. There is also a well-known unique relationship between the angle and energy of single elastic scattering, for a given source energy and element mass number. Therefore, by measuring the energy spectrum of single scattered neutrons at a particular angle, the presence and density of a particular element can be identified by monitoring the portion of the energy spectrum corresponding to the mass number of the desired element. Moreover, neutron scattering in the few MeV range exhibits resonance energies which differ from an element to another. This can be further exploited to enhance the detection of a particular element, say nitrogen in explosives. By varying the source energy, the presence of other elements can also be enhanced. Scattering information may even be utilized for constructing tomographs of the object. In a pulse mode, time of flight information may be utilized to provide the spatial distribution of the sought elements.

The scattering phenomenon has not been fully exploited, mainly due to the fact that measuring the energy spectrum of neutrons is a not a trivial task. However, the author and co-workers have empirically utilized a combination of scattering and transmission measurements to detect the presence of an explosive-like material, a nitrogen-rich fertilizer. A non-collimated and non-moderated californium-252 source was utilized, and a number of detectors were located to monitor the scattering and transmission of neutrons impinging on a test section. By mapping the scattering and transmission measurements versus each other, the presence of the explosive-like material was identified. Although this concept is in its infancy, it has the attraction of requiring a small neutron source; thus reducing the size and cost of the device.

Acknowledgment

This paper is an abbreviated and updated version of a previously published article by the author entitled "Detection of Explosive Materials using Nuclear Radiation: a Critical Review", which appeared in Aviation Security Problems and Related Technologies: Critical Reviews of Optical Science and Technology, W.H. Makky, ed., SPIE-The International Society for Optical Engineering, Vol. CR42, pp. 126-136, 1992. A list of relevant references is given in the original article.

4th International Confernece on CANDU Fuel

Ed. Note: The following is based on notes provided by David Cox and Mark Floyd, conference chair and program chair, respectively, of the recent successful conference on CANDU fuel.

Over 125 delegates from 14 countries gathered in Pembroke, Ontario, October 1 to 4, 1995, for the **4th International Conference on CANDU Fuel**. The previous conferences had been held in 1986, 1989, and 1992.

With a theme of *"CANDU Fuel: Safe, Reliable, Economical"*, the conference objective was to provide an international forum for discussion of topics related to CANDU fuel of interest to utilities operating CANDUs, to those involved in development, engineering and manufacturing, and to organizations or countries interested in CANDU.

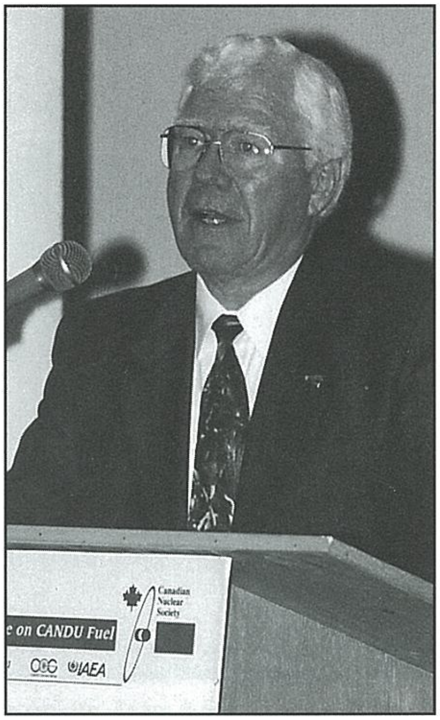
Co-sponsored by the Canadian Nuclear Society and the CANDU Owners Group in conjunction with the International Atomic Energy Agency, the conference attracted delegates from several countries contemplating the adoption of CANDU, including China, Egypt and Turkey as well as from countries with CANDU programs, Argentina, Korea and Romania. There were also representatives from Belgium, France, Japan, the United Kingdom and the USA. Among the Canadian contingent were a number from Atomic Energy of Canada Limited's Chalk River and Whiteshell laboratories and from the engineering group at Sheridan Park, as well as from Ontario Hydro, Hydro Quebec, Zircatec, GE Canada, Cameco, and the Atomic Energy Control Board.

A session of invited papers provided overviews of nuclear fuel programs in Canada, Korea, Romania, Argentina, Pakistan and Egypt. Other sessions addressed fuel performance, design, testing and manufacturing, licensing and accident analyses, advanced fuel cycles, fuel behaviour modelling, and measurement of fuel properties. There were 65 papers presented over the three days of the conference.

Much of the conference program was devoted to fuel behaviour analysis related to safety and licensing and to advanced fuel cycles and fuel designs. The current performance of CANDU fuel was noted to be very good. However, in light of evolving fuel cycle initiatives around the world advance CANDU fuel cycles are being developed to take further advantage of the neutron economy of CANDU reactors. Operational constraints faced by utilities operating CANDUs provide another incentive for design evolution.

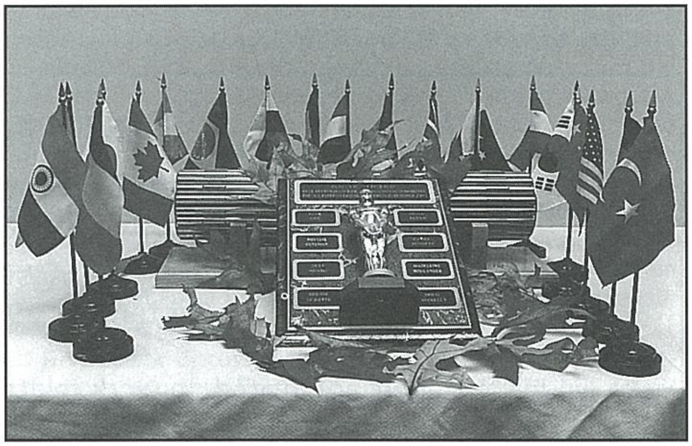
At the banquet, Paul Scholfield, former executive vice-president of GE Canada - Power Systems, spoke on the evolution of CANDU fuel design and manufacturing in Canada. He noted the current climate of change pervading the nuclear industry with impending deregulation of the electric utilities and diminishing government resources.

After the meeting, conference chair David Cox commented that he believed that the conference was successful in bring



Former GE Canada vice-president Paul Scholfield delivers banquet address to the 4th International Conference on CANDU Fuel in Pembroke, October 3, 1995.

Photos by Bernard Surette



Zircatec Precision Industries presented an "Oscar Award" to the organizing committee of the 4th International Conference on CANDU Fuel. Here the award is pictured with a CANDU fuel bundle surrounded by flags of the countries of the delegates. The plaque gives the names of the committee members: David Cox, chair; Mark Floyd, program; Phyllis Gutzman, conference secretary; Cathy Bennett, program secretary; Suli Adams, treasurer; Madelaine Boulanger, facilities; Bernie Surette and Doug Connelly, Publicity.

together a diverse group of researchers, analysts, manufacturers, operators and regulators. The papers presented confirmed the conference theme, that CANDU fuel is safe, reliable and economical."

The excellence of CANDU fuel performance has been clearly established by the operating record", he said. "However, evolution is necessary, both to respond to operating issues and to take advantage of CANDU's fuel cycle flexibility."

Emphasizing the "international" nature of the 4th International Conference on CANDU Fuel in Pembroke, Ontario, October 1-4, 1995, the conference banquet head table guests pose for the camera.

Standing L to R: N. Macici, Hydro Quebec; Dr. R. Olezza, Argentina; Dr. P. Butt, Pakistan; Dr. I. Abdelrazek, Egypt; Dr. I. Uslu, Turkey; Dr. J. Nathwani, COG; Dr. X. Zhu, China; M. Wash, Zircatec; Dr. H. C. Suk, Korea; Dr. B. Moscalu, Romania; V. Langman, Ontario Hydro. Seated: P. Scholfield, GE Canada; D. Cox, AECL; M. Floyd, AECL.

Photos by Bernard Surette

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19th CNS Simulation Symposium

Ed. Note: *The following article is based on a report prepared by Dr. Bill Garland of McMaster University who was the chairman of the recent successful 19th CNS Simulation Symposium.*

Over 50 participants shared their experiences in conducting computer simulation of the complex phenomena associated with nuclear reactors during the two days of the 19th CNS Simulation Symposium which was held in Hamilton, Ontario, October 16 and 17, 1995.

The first simulation symposium was held about 1974 at AECL-SP as an informal meeting of AECL and OH personnel involved in reactor simulation. The idea was to exchange ideas and keep up to date on what each other was doing. This still is the idea and for two days, the participants reported on their work and contemplated how to best utilize the latest that computing technology has to offer.

Jerry Cuttler, the President of the Canadian Nuclear Society, opened the symposium and encouraged non-CNS members to join the CNS. Before the end of the event, some 8 of the 54 participants became members.

Following ia a listing of the papers in the various sessions with comments by the session chairs where available:

Session 1 - REACTOR PHYSICS
Chair: Jim Donnelly, AECL-SP

1 - Comparison of Power Pulses from Homogeneous and Time-Average-Equivalent Models
T.K. De and B. Rouben, AECL Mississauga

2 - Feedback Model of a Grid Based Library for CANDU Reactors Using DRAGON
T. Sissaoui and G. Marleau, Ecole Polytechnique de Montreal

3 - Analysis of the Fast Neutron Spectrum Inside the Experimental Cavity of the NRU Mk4 FN Rod
T.C. Leung, AECL Chalk River

Three papers were presented in the opening session on Reactor Physics, providing a good introduction to the range of current activities and issues in Canada. The first paper, "Comparison of Power Pulses from Homogeneous and Time-Average-Equivalent Models" was presented by T.K. De and co-authored by B. Rouben. The paper described the successful numerical validation of LOCA transient simulations using the time-average-equivalent model in the RESP code against results of the time-average or homogeneous model. The second paper, "Application of the Feedback Model for the History Base using DRAGON", was presented by M.T. Sissaoui and co-authored by G. Marleau. A new method for the treatment of local parameters in CANDU reactor simulations was presented, which provides a promising alternative to overcome the weaknesses of conventional grid-based treatments. The final paper in this session, "Analysis of the Fast-Neutron Spectrum Inside the Experimental Cavity of the NRA Mk4 FN Rod", was presented by T.C. Leung. Analyses of the fast neutron spectrum within in the Fast Neutron rod were described and related to the FN spectral in CANDU pressure and calandris tubes, and the effect of changes in the holder and FN rod on sample irradiation were characterised.

Session 2 - REACTOR PHYSICS
Chair: Peter Laughton, AECL-CRL

1 - Validation of Physics Model of FARE Tool by Comparison of RFSP Flux Simulations with Measurements at Discrete Refuelling Steps
M.A. Shad, AECL Mississauga

2 - Change in CANDU-6 Reactivity Following a Power Reduction at Low PHT Purity
J. Whitlock, AECL Mississauga

3 - REFUEL: Automated Refuelling Program for CANDU Reactors
A. Gray, AECL Mississauga

4 - The Reactor Physics Computer Programs in PC's Era
O. Nainer and D. Serghiuta, Team 3 Solutions

In CANDU-6 reactors the on-power refueling is done in the direction of coolant flow. The hydraulic drag tends to push fuel-bundle strings towards the downstream fuelling machine. In some channels, the coolant flow is low and the hydraulic drag is not enough on its own to move the string. Flow Assist Ram Extension (FARE) tools are used to augment the flow in such channels. While in the reactor core, the FARE tool is a strong neutron absorber, and the resulting flux depression affects reactor control. M.A. Shad presented results of a validation study of the model used by AECL to model CANDU-6 flux perturbations that result from the use of FARE tools. The RFSP and MULTICELL computer codes were used to model detector response, and computational results were compared with detector readings obtained on 1993 July 6 at Point Lepreau when a FARE-tool-assisted refueling was made.

J.J. Whitlock discussed the change in CANDU-6 reactivity following reduction from full power to 80% of full power when heavy-water-coolant purity is low. The latest versions of AECL's RFSP reactor-physics and NUCIRC thermalhydraulics computer codes were used. On reducing power, fuel temperature drops. In addition, not as much subcooled boiling occurs at clad surfaces; average coolant density is increased. Increase in CANDU coolant density tends to decrease reactivity, and this effect is more pronounced when coolant purity is low. The fuel-temperature effect is of the opposite sign, and, in the cases considered in this work, nearly canceled the coolant void effect. Comparisons of the current work with other analyses made at AECL and KAERI were also presented.

A. Gray discussed ongoing development of REFUEL, a computer code that assists in selecting CANDU-reactor channels to be refueled. Elimination rules based on various contraints on channel and bundle power and time between refueling are applied to shrink the set of candidates. The channels to be refueled are determined by performing additional optimization steps. REFUEL produces input for the RFSP program automatically and has been used to make extensive simulations of 480-channel and 380-channel CANDU reactors.

In the final presentation of the session, O. Nainer discussed using modern graphical user interfaces to simplify the construction of input for various computer codes used in reactor physics and to view output on computer screens.

Session 3 - REACTOR PHYSICS
Chair: Andre Beaudouin, HQ

1 - The Burnable Poisons Utilisation for Fissile Enriched CANDU Fuel Bundle
D. Serghiuta and O. Nainer, Team 3 Solutions

2 - The Application of the Goal Programming to CANDU Fuel Management Optimisation
D. Serghiuta and O. Nainer, Team 3 Solutions

3 - Sensitivity of 238U Resonance Absorption to Library Multigroup Structure as Calculated by WIMS-AECL
P.J. Laughton, AECL Chalk River and J.V. Donnelly, AECL Mississauga

4 - Application of the DONJON Reactor Code for Regulating System Simulations
E. Varin, J. Koclas and R. Roy, Ecole Polytechnique de Montreal

Session 4 - HYDROGEN BEHAVIOUR
Chair: Linda Wang, OH

1 - Hydrogen Distribution Studies Relevant to CANDU Containments
M. Krause, D.R. Whitehouse, C.K. Chan and S.C.A. Jone, AECL Whiteshell

2 - Modelling of Hydrogen Deflagration in a Vented Vessel
L. Wang and R.C. Wong, Ontario Hydro

3 - Cell Size Spatial Convergence Analysis on GOTHIC Distributed Parameter Models for Studying Hydrogen Mixing Behaviour in CANDU Containments
K. Yim and R.C. Wong , Ontario Hydro

4 - Hydrogen Distribution Analysis for CANDU Containment Using GOTHIC
T.H. Nguyen and W.M. Collins, AECL Mississauga

Many people were involved actively and many questions were asked on each paper. Different points of view on hydrogen deflagration issues, which were useful, were presented.

Session 5 - THERMALHYDRAULICS
Chair: Mike Carver, AECL-CRL

1 - An Improved Methodology for Addressing Coolant Inlet Temperature Variations when Calculating NOP Trip Set-points
D. Buchan, Ontario Hydro

2 - Gas Resolution and Released Models in Reactor Thermal-Hydraulics
E. Zaltsgendler, W.S. Liu and R.K. Leung, Ontario Hydro

3 - Experimental and Numerical Study of ingle-Phase Heat Transfer Enhancement n a Tube
S. Doerffer, A.O. Banas and H.C. Wang, AECL Chalk River

4 - ASSERT Software Quality Assurance, Benchmark Testing and Parametric Studies
J.C. Kiteley, M.B. Carver, G.M. Waddington and S.V. Junop, AECL Chalk River

Session 6 - THERMALHYDRAULICS
Chair: Ray Leung, OH

1 - ASSERT Validation Against the Stern Laboratory Pressure Drop Tests
G.M. Waddington, J.C. Kiteley and M.B. Carver, AECL Chalk River

2 - Prediction Methods of CHF and Pressure Drop for a 37-Element Bundle String Inside Crept Channels
L.K.H. Leung, D.C. Groeneveld, AECL Chalk River and G. Hotte, Hydro-Quebec

3 - Detection of Damped Flow Oscillations in a CANDU 6 SOPHT Simulation using Noise Perturbations
Y. Gao, H.W. Hinds, P. Tonner, P. Kumli and D. Black, AECL Chalk River

4 - Modelling CWIT Refill Test 1465 Using CATHENA
J.P. Han, W. Thompson, Atlantic Nuclear Services Inc. and A. Gallia, New Brunswick Power

In this session interesting and valuable papers were presented by Geoff Waddington, Lawrence Leung, Yang Gao and Jim Han. Questions and active discussions followed each presentation. The speakers emphasized the proper use of modelling parameters and correlations.

Session 7 - REACTOR SAFETY AND OPERATION
Chair: Dave Jenkins, AECL-SP

1 - CANDU-9 Nuclear Power Plant Simulator
M. Kattan, M. MacBeth, AECL Saskatoon and K. Lam, CTI Toronto

2 - MAAP-CANDU Simulation of Severe Accidents in Darlington NGS
M.H. Choi, M.T. Kwee, R.K. Leung and S.G. Lie Ontario Hydro

3 - Fault Detection and Diagnosis Using Statistical Control Charts and Artificial Neural Networks
R. Leger and W.J. Garland, McMaster University

4 - Rapid Assessment of Atmospheric Releases for Nuclear Emergency Response Planning
R. de Wit, D. Spagnolo, Quanta Technologies Group Inc. and S. Kupca, Department of National Defense

The first paper "CANDU-9 Nuclear Power Plant Simulator", presented by Mahmoud Kattan of AECL Saskatoon and co-authored by Mike MacBeth also of AECL and Kwok Lam of CTI Toronto, described in general terms the CANDU 9 nuclear power plant simulator which has been developed with an "off the shelf" dynamic simulation development system software package (CASSIM). The simulator uses low fidelity models to allow rapid simulation and is intended for use in the plant design stage to provide rough tuning parameters and to proof data transfer between the plant and operator, the distributed control system and plant display system.

The second paper "MAAP-CANDU Simulation of Severe Accidents in Darlington NGS" was presented by Mark Choi and co-authored by M.T. Kwee, R.K. Leung and S.G. Lie of Ontario Hydro RSOAD. Mark presented a computer aided dynamic display of the MAAP-CANDU program simulation of a postulated large LOCA with containment bypass coincident with impairment of the ECIS, moderator, and shield tank heat sinks. The analysis shows that Darlington has design characteristics that are inherantly tolerent of severe accidents and that there are ample opportunities for operator intervention to mitigate or arrest the accident sequence.

The third paper "Fault Detection and Diagnosis Using Statistical Control Charts and Artificial Neural Networks" was presented by Robert P. Leger and co-authored by W.J. Garland and W.F.S. Poehlman of McMaster University. The paper demonstates that the use of cumulative summation (CUSUM) control charts linked using fault signature patterns for specific faults to a radial basis function neural network has promising potential for process fault detection and diagnosis.

The last paper in this session "Rapid Assessment of Atmospheric Releases for Nuclear Emergency Response Planning" was presented by Rob de Wit and co-authored by D. Spagnolo (both of Quanta Technologies Group Inc.) and S. Kupca of the Department of National Defence. Rob demonstrated the use of the atmospheric dispersion code PEARL in tandem with the code NERP to evaluate the effectivness of response schemes in reducing doses obtained from atmospheric releases. The analysis showed that a probabilistic treatment of weather offers considerable improvement over the more traditional deterministic analysis and provides a basis for more appropriate and optimized planning and resource allocation in the event of a nuclear emergency.

Session 8 - REACTOR SAFETY AND OPERATION
Chair: Jean Koclas, Ecole Polytechnique

1 - Determination of Critical Break for Large Break Loss-of-Coolant Accident Analysis
J.D. Hoskins and W. Chan, Ontario Hydro

2 - Large Break Loss-of-Coolant Accident Coincident with Loss of Class IV Power Analysis
P. Ta, AECL and W. Chan, Ontario Hydro

3 - Reactor Operation with Flux Tilt: Darlington NGS
A.H. Oslinger and A.E. Attia, Ontario Hydro

4 - In-Core LOCA's: Analytical Solution for the Delayed Mixing Model for Moderator Poison Concentration
A.P. Firla, Ontario Hydro

Symposium chairman Bill Garland thanks after-dinner speaker Bob Nixon, chairman of the board of AECL, at the banquet of the 19th Simulation Symposium held in Hamilton, 16, 17 October 1995.

The guest speaker at the Symposium dinner was Robert Nixon, Chairman of the Board, AECL.

Mr. Nixon noted that Nuclear Canada is at a watershed given our large national debt, our aging facilities, and our need for a NRU replacement to carry on fundamental nuclear science and CANDU based research and development. He suggested that we need to act as national nuclear team. His presentation illustrated the broader issues and added relevance to the simulation tasks that are the daily fare of the symposium participants.

The symposium planning and execution went absolutely smoothly, thanks to the superb efforts of the organizational team:

- Guy Marleau, Ecole Polytechnique, who took care of the technical program with assistance from his colleagues at Ecole and from Ray Leung, Ontario Hydro. The technical program is, of course, centrally important to the success of the event. Guy and the session chairs made the technical program happen.

- Rob Leger, Graduate Student, McMaster University, was the symposium coordinator and did an absolutely superb job. His organizational skill defines a class by itself.

- Simon Day, Graduate Student, McMaster University, was the symposium treasurer, entrusted with the crucial task of ensuring that the symposium operated in the black.

-Jan Arsenault and Ginny Riddell, DOCU-Centre, McMaster University, provided all the coordination of the local program, liasion with the hotel, registration, liaison with CNS HQ, mailing, proceedings and so much more.

19th CNS Simulation Symposium - Selected Abstracts

***Ed. Note:** To augment the report on the 19th CNS Simulation Symposium and to give readers some additonal flavour of the papers given, following are a few abstracts, selected rather arbritarily by the editor, from the four topical subject areas; reactor physics; hydrogen behaviour; thermalhydraulics; safety and operation.*

Reactor Physics

The Burnable Poisons Utilization for Fissile Enriched CANDU Fuel Bundle

Dumitru Serghiuta, Ovidiu Nainer

Team 3 Solutions

Abstract and Conclusions

Utilization of burnable poison for the fissile enriched fueled CANDU 6 Mkl core is in~iestigated. The main incentives for this analysis are the reduction of void reactivity ef~ects, the maximization of the fissile content of fresh fuel bundle and the achievement of better power shape control, in order to presen,~ the power en~elope of the standard ~7 rod fu~l bundle.. The latter allows also the preservation of construction parameters of the standard core (for e~ample: number and location of reactivity de~,ices). It also permits the use of regular shift fueling schemes. The paper makes an analysis of MOX- weapons-grade plutonium- and 1.2% SEU fueled CANIDU 6 Mk 1 core.

The analysis of the burnable poison utilization for fissile enriched CANDU fuel bundle revealed the following aspects:

- the feasibility of weapons-grade plutonium bulning in CANDU 6Mkl core, in a forn of mixed CANDU spent fuel and Pu239, using the standard 37 rod fuel bundle;
- the optimal result is a fuel bundle wrilh a combined different radial grading for the absorbent and fissile materials;
- a zero void reactivity effect can be reached by accepting a penalty in discharge burnup.
- the use of Dy or Eu as bumable poison is proposed

Hydrogen Behaviour

Hydrogen Distribution Analysis for CANDU 6 Containment Using the Gothic Containment Analysis Code

T.H. Nguyen and W.M. Col1ins

AECL

Abstract

Hydrogen may be generated in the reactor core by the 71rc-steam reaction for a postulated loss of coolant accident (LOCA) scenario with loss of emergency core cooling (ECC). It is important to predict hydrogen distribution within containrnent in order to determine if flammable mixtures exist. This information is required to determine the best locations in containment for the placement of mitigation devices such as igniters and recombiners.

For large break loss coolant accidents, hydrogen is released after the break flow has subsided. Following this period of high discharge the flow in the containment building undergoes transition from forced flow to a buoyancy driven flow (particularly when local air coolers (LACS) are not credited).

One-dimensional computer codes (lumped parameter) are applicable during the initial period when a high degree of mixing occurs due to the forced flow generated by the break. During tbis period the homogeneous assumption of lumped codes is applicable. However, during the post-blowdown phase (when the break flow has subsided) the assumption of homogeneity (particularly in large volumes) becomes less accurate and it is necessary to employ three-dimensional codes to capture local effects. This is particularly important for purely buoyant flows which may exhibit stratification effects.

In the present analysis a three-dimensional model of CANDU 6 containment was constructed with the GOTHIC computer code using a relatively coarse mesh adequate enough to capture the salient fealures of the flow during the blowdown and hydrogen release periods. A 3D grid representation was employed for that portion of containment in which the primary flow a.(LOCA and post-LOCA) was deemed to occur. The remainder of containment was represented by lumped nodes. The results of the analysis indicate that flammable concentrations exist for several minutes in the vicinity of the break and in the steam generator enclosure. This is due to the fact that the hydrogen released from the break is primarily directed upwards into the steam generator enclosure due to buoyancy effects. Once hydrogen production ends, the concentrations in these areas become non-flarnmable again. In the boiler room (volume above the reactivity mechanisms deck) flamable mixtues are not predicted due to the large volume available for mixing. In other areas of containment, particularly below the break, flammable mixtures are not predicted as there is insufficient forced flow to propagate hydrogen downwards.

Thermalhydraulics

Experimental and Numerical Study of Single-Phase Heat Transfer Enhanced in a Tube

S. Doerffer, A.O. Banas and C.H. Wang

Chalk River Laboratories, AECL,

Abstract

CANDU fuel channels use bearing pads and spacers to maintain respectively, the bundle separation from the

pressure tube, and the separation of the fuel elements from each other. These appendages significantly affect pressure drop and heat transfer in single phase flow under normal operating conditions, and also can increase channel dryout power. To understand the heat transfer enhancement and pressure-drop mechanisms of such flow obstructions, systematic experimental and numerical investigations are required for various configurations of flow obstruction, under a range of power and flow conditions.

Previous numerical simulations of local hydrodynamics and heat transfer in obstructed channel geomelries, employing the general purpose computational fluid dynamics (CFD) software, TASCflow, were presented elsewhere. They established a proof of concept for CFD-based prediction methodologies, but lacked experimental validadation. To address this concern, an experimental program was launched to provide a data base for systematic validation of TASCflow turbulence and heat-transfcr models over the range of Reynolds numbers of interest to CANDU channel operating conditions.

The heat transfer and pressure drop were investigated in the MR-7A loop at Chalk River Laboratories using single phase Freon-134a as a coolant. The test section was a vatical 8 mm ID directly heated tube, made of Inconel 600. Two ring-shaped flow obstructions werc tested; they reduced the flow area by 17.8% and 30%. The pressure of the flow obstructions enhanced heat transfer up to 38% and 61%, respectively. Thesc significant changes were observed in the downsstream region, over a very short distance behind the obstruction. Thr tests were carried out within the mass flux range of 1 to 6 MB/m2s, and the highest relative heat transfer enhancement occured at I Mg/m2s. The pressure drop increase due to the flow obstructions was chracterized by the form loss factor, K, which was found to be 0.18 and 0.45, for the 17.8% and 30% rings, respectively.

The heat-transfer enhancement and pressure-drop experiments were subsequently simulated numerically using TASCflow software. All simulations were preformed assuming axisymmeetric flow conditions, and employing the standard k-ε model for turbulent flows. Both forced convection in freon and conjugated heat conduction in the ring and the tube walls were considered. The predictions generated by the code agreed well with the experimental results for both heat transfer and pressure drop. This demonstrates the merit of computational, CFD-based methodology for assessmcnt of appendage effects in single-phase forced convection flows.

Safety and Operation

In-Core LOCAs: Analytical Solution for the Delayed Mixing Model for Moderator Poison Concentration

A.P Firla
Ontario Hydro

Abstract

Solutions to dynamic moderator poison concentration model with delayed mixing under single pressure tube / calandria tube rupture scenario are discussed. Such a model is described by a delay differential equation and for such equations the standard ways of solution are not directly applicable. In the paper an exact, direct time-domain analytical solution to the delayed mixing model is presented and discussed. The obtained solution has a "marching" form and is easy to calculate numerically.

Results of the numerical calculations based on the analytical solution indicate that for the expected range of mixing times the existing uniform mixing model is a good representation of the moderator poison mixing process for single PT/CT breaks. However, for postulated multi-pipe breaks (which is very unlikely to occur) the unifirm mixing model is not adequate any more; at the same time an "approximate" solution based on Laplace transform significantly overpredicts the rate of poison concentration decrease, resulting in excessive increase in the moderator dilution factor. In this situation the true, analytical solution must be used.

The analytical solution presented in the paper may also serve as a bench-mark test for the accuracy of the existing poison mixing models. Moreover, because of the existing oscillatory tendency of the solution, special care must be taken in using delay differential models in other applications.

AECL's progress in developing the DUPIC Fuel Fabrication Process*

by J.D. Sullivan & D.S. Cox — AECL, Chalk River Laboratories

ABSTRACT

Spent Pressurized Water Reactor (PWR) fuel can be used directly in CANDU reactors without the need for wet chemical reprocessing or reenrichment. Considerable experimental progress has been made in verifying the practicality of this fuel cycle, including hot-cell experiments using spent PWR fuels and out-cell trials using surrogate fuels. This paper describes the current status of these experiments.

INTRODUCTION

Atomic Energy of Canada Limited (AECL), the Korean Atomic Energy Research Institute (KAERI) and the United States Departments of State and Energy (US DOS/DOE) are involved in a joint program to develop a process for the Direct Use of spent PWR fuel in CANDU reactors (DUPIC). This involves reconfiguring spent PWR fuel into a form that can be used in a CANDU reactor without using conventional, wet reprocessing technology. This provides a proliferation-resistant fuel cycle that does not involve wet chemistry at any stage of the process.

The reference PWR fuel for this project is 3.5% U-235 at start of life, with a discharge burnup of 35 MWd/kgU. This is typical of Korean spent PWR fuel. The residual fissile content of this spent fuel is sufficient to burn in a CANDU reactor without the addition of more fissile material. Although the achievable burnup with this fuel will depend on details of the bundle design, the burnup is approximately 18 MWd/kgHM, which compares to natural uranium burnups in CANDU of around 7.5 MWd/kgU.

A Phase I study, looking at various reconfiguration methods, has been completed. The process that was recommended is OREOX, a process in which dense UO_2 pellets are broken down into a ceramic-grade powder by cyclic oxidation and reduction, and the resulting powder is pressed and sintered into CANDU-quality pellets that are assembled into CANDU bundles.

Phase II, an experimental verification to demonstrate the feasibility of the OREOX process, is now underway. There are a number of issues being addressed, including:

- a decladding technology to separate spent PWR fuel from its cladding,
- optimizing the OREOX cycle to produce a sinterable powder,
- remotely fabricating CANDU-quality pellets, elements and bundles,
- trapping and disposing of volatile fission products throughout the process,
- irradiation testing DUPIC fuel to measure fuel performance,
- extending modelling codes to include DUPIC fuel, and
- establishing safeguards procedures for the entire process.

All of the processing and fabrication activities must be performed in a hot-cell environment.

The workscope for this phase of the project is divided among the various members as follows:

- Development of fuel-element fabrication technology ....AECL
- Development of fuel-bundle fabrication technology ....KAERI
- Reactor physics and safety analysis ....Joint AECL/KAERI
- Verification of irradiation behaviour ....KAERI (with AECL)
- Safeguards ....US/KAERI

The results described here focus on advancements by AECL in optimizing the OREOX cycle.

OREOX PROCESS

A number of possible reconfiguring technologies were assessed during Phase I, and the one chosen for further study was OREOX. The OREOX process uses crystallographic phase transitions in uranium oxides to break the initial UO_2 pellets into fine powders. Oxidizing UO_2 into U_3O_8 results in a transition from a cubic to an orthorhombic structure, with an associated volume increase of 32%. The cyclic transformation between cubic and orthorhombic phases causes microcracking in the matrix, and the production of a fine powder. If the powder can be made fine enough, it can be processed as a ceramic-grade powder into CANDU-quality fuel pellets, for assembly into CANDU fuel bundles.

The OREOX process has a number of steps, including:

- decladding the spent PWR fuel,
- subjecting the exposed fuel to alternating cycles of oxidation and reduction, to produce a fine powder,
- any subsequent powder conditioning (i.e., milling) required to improve the sinterability of the powder,
- fabricating CANDU-quality fuel pellets from that powder,
- loading the pellets into sheaths,
- assembling the CANDU bundles, disposing of irradiated PWR assembly hardware, and
- trapping and disposing of volatile fission products released during the decladding, OREOX and sintering processes.

A schematic flowsheet of the OREOX process is shown in Figure 1.

* Paper presented at International Conference on CANDU Fuel

Hot-cell and pilot-scale out-cell experiments are being performed in parallel during the development phase of this project.

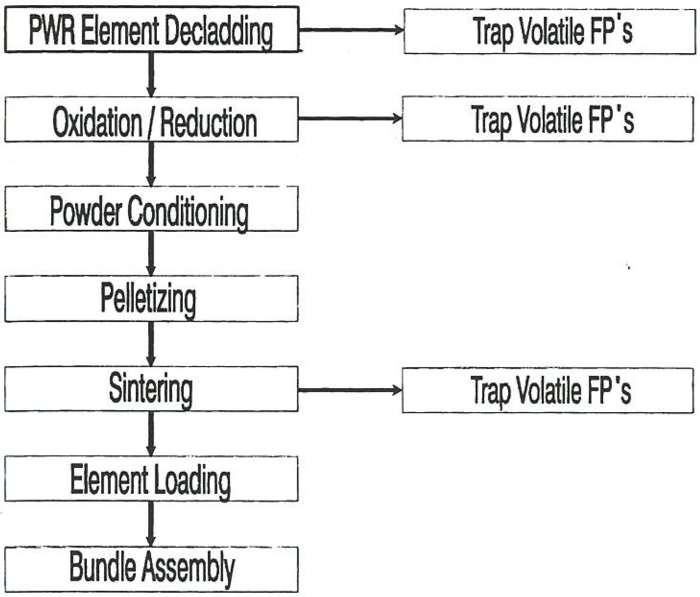


FIGURE 1 *Schematic flow sheet for the OREOX Process*

HOT-CELL EXPERIMENTS

Hot-cell experiments using small quantities of irradiated PWR fuel (between one and three pellets), have investigated fission-product (FP) release during various OREOX thermal cycles. Volatile FP's are expected to be released during the OREOX process, including noble gases (krypton and xenon), cesium, iodine and possibly ruthenium. It would be desirable to have volatile FP's removed in the (relatively low temperature) OREOX furnace, rather than in the (more complex and sophisticated) sintering furnace. To facilitate this, various OREOX schedules were examined to investigate FP release.

A horizontal tube furnace with a 7.5 cm diameter alumina tube was used for these experiments. Fuel samples were contained in alumina boats mounted in alumina trays that were inserted into the furnace tube. Appropriate gases (air, Ar/4% H_2, Ar/12%CO or CO_2) were flowed into the furnace tube and out into the hot-cell ventilation system after scrubbing through an appropriate filter system. Because of safety constraints in the hot cells, the hydrogen content of reduction gases did not exceed 4%.

Two spent PWR fuels were used for the in-cell tests. Fuel A had an initial enrichment of 2.55% U-235, achieved a burnup of 28 MWd/kgU (672 MWh/kgU), and was discharged in 1974 May. Fuel B was initially 3.5% U-235, achieved 57 MWd/kgU (1375 MWh/kgU), and was discharged in 1988 February. Although neither fuel duplicates the reference spent PWR fuel specifications, they do bracket the conditions (one a lower initial enrichment and burnup, the other the correct initial enrichment but a higher burnup). The trend in nuclear power is to higher burnups, making this high-burnup information important.

OREOX trials were conducted using a number of thermal cycles. It was found that Fuel A (28 MWd/kgU) was rapidly oxidized at approximately 400°C (which is consistent with 4-atom% SIMFUEL** results), and only partially oxidized at 350°C. Fuel B (57 MWd/kgU) did not appear to be oxidized until the temperature was raised to 500°C. Thus the burnup of the fuel has a significant impact on the OREOX schedule to be used.

FP release was monitored during the various OREOX cycles. 9~% of the cesium was released after 3.9 hours at 1400°C, whereas 76% was released after 1.4 hours at 1320°C. Approximately 3.5% of the krypton was released from Fuel A at 400°C, whereas 30% of the krypton was released from Fuel B under similar conditions. Ruthenium was released rapidly during heating to 1400°C, whereas no europium was released during any of these tests. There was no release of FP's during the reduction portions of the schedules (except for a small amount of krypton released during the first two cycles). FP release is summarized in Table I.

Resultant powder morphologies were similar to those found in initial out-cell trials during commissioning of the apparatus. Equipment was not available for these first in-cell trials, to investigate powder sinterability.

	Low Temperature (400°C)		High Temperature (1400°C)
	Fuel A	Fuel B	
Cesium	<1%	<1%	98%
Krypton	3.5%	30%	100%
Ruthenium	<1%	<1%	100%
Europium	0%	0%	0%

TABLE 1 *Fission-product removal from spent PWR fuel*

PILOT-SCALE PROCESSING

Powder and pellet fabrication properties were examined during out-cell pilot-scale processing. These experiments looked at variables such as cycle temperatures, powder bed depth, gas-flow rates and dwell times at temperature. Powder characterization was performed on all powders. The important powder parameters are: particle-size distribution, surface area, and sinterability. Scanning Electron Micrograph (SEM) analysis is the best method of characterizing irradiated fuel powder, and this method was therefore also used to "bench-mark" powders produced during pilot scale OREOX trials.

All out-cell tests used SIMFUEL simulating fuel with 4 atom% burnup (approximately 35 MWd/kgU). The composition of the SIMFUEL is listed in Table II. Because SIMFUEL is a sintered product composed of stable additives, it contains no volatile elements. The primary importance of SIMFUEL tests in these experiments is to determine the sinterability of powders fabricated by various OREOX cycles.

During the initial pilot-scale trials, a high-temperature oxidation stage (1100°C) was included in the first cycle. Subsequent cycles were: reduction in Ar/4%H_2 at 700°C and oxidation in air at 400°C. The intent of the high-temperature

** SIMFUEL is UO2 containing stable chemical additives that simulate the composition of irradiated fuel.

Element	Also Representing	g/gU %
Ba		0.22
Ce	Np	0.28
La	Am, Cm	0.14
Mo		0.40
Sr		0.08
Y		0.05
Zr		0.40
Rh		0.05
Pd		0.22
Ru	Tc	0.29
Nd	Pr, Pm, Sm	0.47

TABLE 2 *Composition of 4 atom%-burnup SIMFUEL*

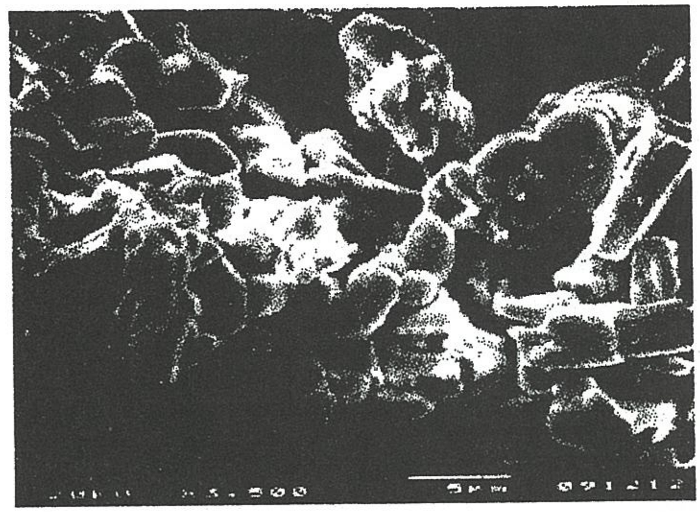


FIGURE 3 *Scanning electron micrograph of OREOX powder after a series of heat treatments, including a high-temperature oxidation.*

oxidation was to drive off volatile FP's before reaching the sintering furnace. Note that, although these experiments were performed out-cell, the hydrogen content of reduction gases was kept down to 4%, to be consistent with the small scale hot-cell and future pilot-scale experiments that will be done in-cell.

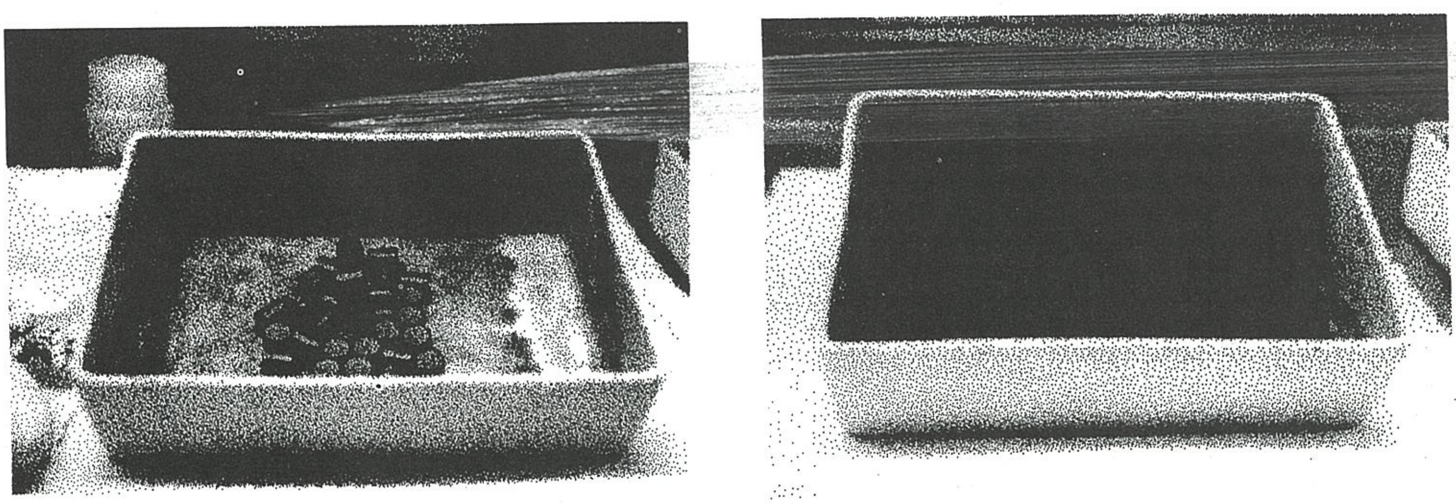
The initial oxidation at 1100°C was performed in a regular box furnace. All subsequent processing was in a box furnace with an extended hot zone and a stainless-steel hydrogen retort. Alumina trays 18 cm x 14 cm x 6 cm were used to contain the pellets and powder in the furnace during processing. A tray of as-fabricated SIMFUEL pellets is shown in Figure 2A). The same pellets after the OREOX process are shown in Figure 2B).

SEM investigation of as-produced powder indicated that it was very coarse (>5 µm), with a smooth surface and some indication of laminations in particles. A SEM of this powder is shown in Figure 3. Pellets made from this powder crumbled on exit from the die and it was not possible to make sintered samples.

To increase the sinterability of the powder, it was subjected to dry vibratory milling for 1 hour using cylindrical zirconia media (12.5 mm dia. x 12.5 mm tall). Pellets fabricated from this powder sintered to a density of 9.9 g/cm^3 (approximately 92% of the theoretical density of 4 atom% burnup SIMFUEL). The poor sinterability of this powder is attributed to the coarseness introduced during the initial high-temperature oxidation stage.

The second set of pilot-scale trials did not include the high-temperature oxidation, and used only three cycles of oxidizing in air at 400°C and reducing in Ar/4%H_2 at 700°C. All oxidation and reduction was done in the large box furnace with the stainless-steel retort. The as-produced powders had a mean particle size of 2.4 µm (50% mass level as measured by sedimentation) and a surface area of 4.0 m^2/g. A SEM is shown in Figure 4. Some of this powder was also vibratory milled, as above. After milling, the particle size was 1.7 µm and the surface area was 6 5 m^2/g.

FIGURE 2 *ALUMINA TRAY WITH SIMFUEL PELLETS A) before and B) after the OREOX Process*



A B

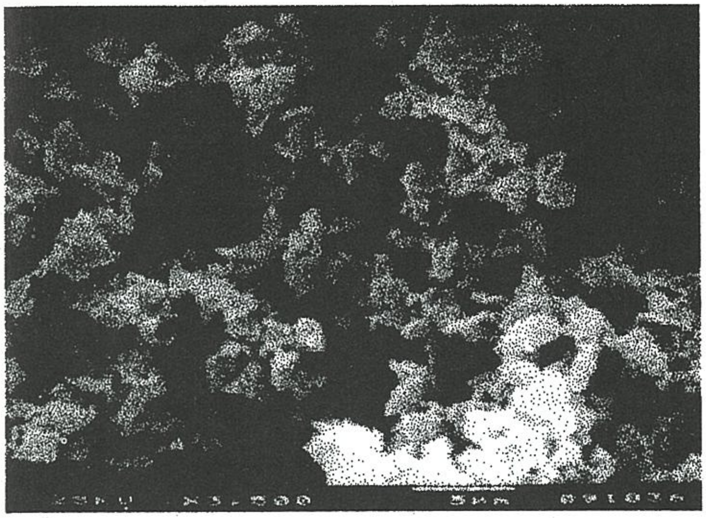


FIGURE 4 *Scanning electron micrograph of OREOX powder after only low-temperature oxidations*

Pellets were fabricated from both powders and sintered. The sintered densities were: as produced 96.5% of the theoretical density of 4 atom%-burnup SIMFUEL, after milling 97.9% of theoretical density. Both are within the CANDU-specified window of 95.3% to 98.1% of the theoretical density (of fresh UO_2).

Overall, it was found that OREOX pellets made from SIMFUEL powders that had been subjected to a high-temperature oxidation stage did not sinter to a high density, whereas those that did not experience this step had adequate sinterability.

CONCLUSIONS

Although high-temperature oxidation is effective in driving off volatile fission products, it causes the formation of coarse granules that are resistant to further size reduction and have poor processing/sintering characteristics.

The hot-cell FP release results can be summarized as:

- 98% of the cesium was released after 3.9 hours at 1400°C, whereas 76% was released after 1.4 hours at 1320°C.
- Approximately 3.5% of the krypton was released from Fuel A at 400°C, whereas 30% of the krypton was released from Fuel B under similar conditions.
- 100% of the ruthenium was released rapidly during heating in air to 1400°C.
- No europium was released during any of these tests.
- There was no release of FP's during the reduction portions of the schedules (except for a small amount of krypton released during the first two cycles).

These results imply that restricting the oxidation temperature to less than 500°C will result in significant quantities of cesium remaining in the fuel during the OREOX process and being released in the sintering furnace. There is no indication yet of how ruthenium, europium or cesium will behave in a sintering furnace.

Dry vibratory milling was found to improve the sinterability of as-produced powders.

High-density pellets, meeting CANDU specifications for sintered density, can be produced on a pilot scale using an OREOX cycle and SIMFUEL.

FUTURE ACTIVITIES

The DUPIC project has had a very promising start and is gaining momentum. Future work will continue to optimize the OREOX cycle on both a small scale, using spent PWR fuel, and on a pilot scale, using SIMFUEL.

In parallel with this, in-cell efforts will be scaled up, leading to the fabrication, using spent PWR fuel, of both OREOX fuel elements (by AECL) and bundles (by KAERI) for a research reactor irradiation. These elements and bundles will then be subjected to post-irradiation examination. Fuel performance modelling codes will then be extended to include DUPIC fuel.

All partners in the project (AECL/KAERI/DOS/DOE) will continue to work towards the establishment of safeguards procedures and equipment.

ACKNOWLEDGEMENTS

The efforts of Zhendong Liu, Don Semeniuk and Bob O'Connors in obtaining fission-product release data, and Blain Clatworthy in pilot-scale processing of SIMFUEL, are gratefully acknowledged.

CNS news

BRANCH NEWS

Ed. Note: Most of the following is drawn from the report by Ben Rouben, 2nd vice-president and chairman of Branch activities.

BRUCE

On October 12 Ken Hedges gave a talk on "AECL Product Development" in which he outlined the markets, factors and strategies which are guiding AECL's business plan. He reviewed the status of the major products, CANDU 3, CANDU 6 and CANDU 9 and the prospects for Wolsong 5 and 6.

Planned meetings are:

December 7 with Bill Garland of McMaster University speaking on "Research Reactors - Their Use and Their Future";

December 14 with Ian Hastings of AECL speaking on "The Irradiation Research Facility - The Case and the Concept".

CHALK RIVER

The Branch was very busy during the summer organizing the 50th Anniversary celebrations which were held August 4-6 (see separate article). On September 5, the actual 50th anniversary of the start-up of ZEEP, Terry Rummery, former president of AECL Research spoke on "Scientific and Engineering Research - Who Needs It ?"

On October 11, Bill Hancox, AECL vice-president, spoke on future plans for AECL. A series of talks is being planned for the coming season.

DARLINGTON

The new chair of the Darlington Branch is Richard Murphy.

On October 5, Stephen Yu of AECL made a presentation on CANDU 9. In November Dan Meraw will talk about his experiences as a member of an IAEA OSART team reviewing the Ignalina plant in Lithuania. Also plans are being made for a visit to Ontario Hydro's Control Centre in Clarkson.

GOLDEN HORSESHOE

The Branch has taken the initiative of producing a CNS page on the World Wide Web. (see separate article). Members of the Branch were very much involved with the 19th CNS Simulation Symposium which was held in Hamilton in October (see separate articles).

MANITOBA

The Branch organized a special seminar with Noel laureate Dr. Bertrand Brockhouse on October 16.In November Dr. J. Jovanovich of the University of Manitoba is scheduled to speak on the risks of low-level radiation. It is planned to follow this with another presentation on the biological effects of low levels of radiation.Other talks on the Sudbury Neutrino Observatory and the relation of the media and the nuclear industry are planned.

NEW BRUNSWICK

Paul Unrau of AECL Chalk River Laboratories spoke October 18 on "Genetics, Biology and Risk Management" which proved to be very popular. The executive for 1995-96 has not yet been chosen.

OTTAWA

Mohamed Lamari, a Ph.D. student at Carleton University, has taken over as chairman.

Plans for the season are still being developed but include a talk by Joe Wallach of the AECB in November on seismic risks and two more technical meetings in the new year. The Branch will be very much involved in the next CNS/CNS Student Conference (the Branch chairman is co-chair of the conference) which will be held in Ottawa on March 15-16, 1996.

As last year, the Branch will be organizing a field trip for Ottawa area high school students and is participating in the regional Science Fair.

PICKERING

The Branch began the season with a talk on September 27 by Bob Stasko of the Canadian Fusion Fuels Technology Project on the initiatives to have the International Thermonuclear Experimental Reactor sited in Canada.

QUEBEC

The Quebec Branch now operates two divisions, one in Montreal and the other at Gentilly. Willem Joubert continues to head the Montreal group while Henri Bordeleau has taken on the role at Gentilly.

An interesting tour of CAE Electronics Ltd. was held on October 19. CAE builds simulators for the aviation and nuclear industries.

SASKATCHEWAN

The Branch organized several activities associated with a visit by Nobel laureate Dr. Bertrand Brockhouse, October 12, 13, including two seminars on "Slow Neutron Spectroscopy and the Grand Atlas of the Physical World" at the University of Saskatchewan in Saskatoon and the Regina Campus. A laminated "Brockhouse" poster was presented to Dr. Brockhouse and his wife at the lunch on October 13 and the Branch hosted a reception after the Regina talk.

It is planned to have Dr. Bernie Cohen present a seminar in November.

SHERIDAN PARK

Ralph Green, former vice-president of AECL Research gave a talk, September 27, on "ZEEP, the Little Reactor that Could" (see article in this issue). On October 19 Gary Kugler, vice-president, commercial of AECL, spoke to an over-flowing audience on "CANDU Sales Prospects".Tentatively planned are talks by Dan Meneley, AECL chief engineer, and Reid Morden, AECL president.

TORONTO

On September 27 Don Dautovich of the Canadian Fusion fuels Technology Project spoke on the economic benefits of siting ITER, the International Thermonuclear Experimental Reactor, in Canada.

On October 27 a seminar was held on the PHEBUS research program in France.

NEWS OF MEMBERS

Dr. J. T. (Terry) Rogers has been named the first Canadian Fellow of the International Centre for Heat and Mass Transfer.

The Centre was founded in 1968 to promote international cooperation in the fields of heat and mass transfer. Terry has been active with the Centre for many years.

This past summer he chaired an international seminar sponsored by the Centre in Cesme, Turkey. As well as chairing the overall meeting Dr. Rogers presented a paper on "The Coolability of Severely Degraded CANDU Cores" which he co-authored with members of AECL.

DEDICATION

Rob Leger, a graduate student at McMaster University and coordinator of the recent successful 19th Simulation Symposium, became a father just a week before the Symposium. It is reported that Rob survived on adrenalin, caffeine (measured in litres) and minimal sleep (measured in minutes). Congratulations and thanks to Rob and his wife Samantha.

In a similar vein, and associated with the same Symposium, **Jan Arsenault**, who was in charge of registration, facilities, etc., got married to Greg Nurnburg (of AECL Sheridan Park) just two days before the Symposium and still showed up on Monday morning to look after registration! Thanks Jan.

Electronic Conferencing

Reflecting on the successful Simulation Symposium he chaired recently in Hamilton, Bill Garland (a professor at McMaster University and chairman of the CNS Golden Horseshoe Branch) passed on these comments.

"I want to emphasize the importance of strong industry - university linkages. We are in this business together. Let us work together. The important thing is to pursue the issues.

Given the emerging computing and information technologies, we should consider reformatting or enhancing events (such as his symposium) by using electronic remote conferencing such as: e-mail, Internet news groups, list servers*, electronic publishing, and code sharing over the net. We have the technology installed. Let us use it to the fullest."

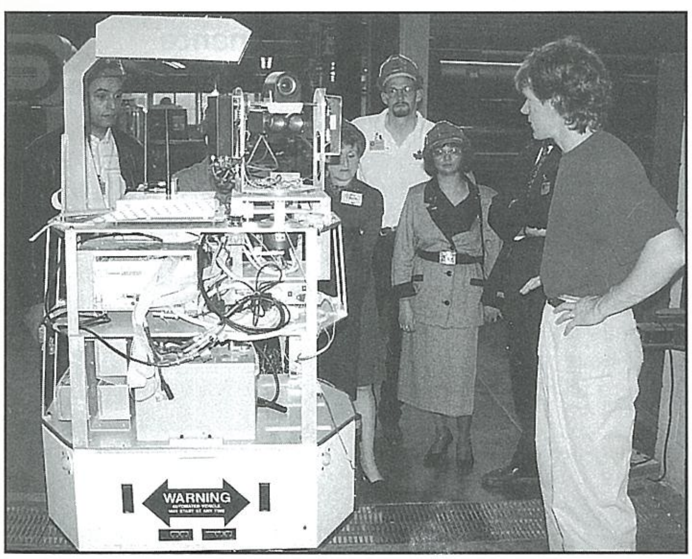
* The CNS Golden Horseshoe Branch listserver is at: listproc@listserv.cis.mcmaster.ca

Membership Time

It is time to renew your membership in the Canadian Nuclear Society.

The regular membership fee for 1996 is $60, BUT, if you renew before the end of February you pay only the current rate of $55.

New membership renewal forms are being mailed out.



Following the CNS officers' Seminar at Sheridan Park, October 20, some attendees toured AECL's Sheridan Park Engineering Laboratory. Here, Dave Wilkes explains some of the capabilities of the ARK robot to (L-R) Mohamed Lamari, Judy Tamm, Rick Murphy and Suli Adams.

Costas Pappas of AECL Montreal and secretary of the CNS Quebec Branch is greeted by Prime Minister Jean Chrtien while Quebec MP Helen Bakopanos looks on, during a recent meeting with a delegation from Greece.

Executive members of the CNS and the recently formed Nuclear society of Russia took the opportunity of their joint attendance at the meeting of the American Nuclear Society in San Francisco in late October to sign an Agreement of Cooperation.
Here, CNS president Jerry Cuttler shakes hands with Valentin Ivanov, president of the Nuclear society of Russia following the signing of the agreement. Looking on are: CNS vice-presidents, Ben Rouben and Hong Huynh and NSR executive secretary Sergei Kushnarev.
Dr. Ivanov is director of the large Research Institute of Atomic Reactors in Dimitrovgrad, about 1,000 kilometres east of Moscow. Dr. Kushnarev is a head of a department in the Kurchatov Institute in Moscow.

CALL FOR PAPERS

1st International Conference on CANDU Fuel Handling Systems

Toronto, Ontario
13, 14 May 1996

This conference, which will focus on fuel handling issues from both the design and operational viewpoints, is aimed at operators, maintenance personnel, technical staff, designers and regulators.
Papers are invited for verbal presentation or for the poster session in the following areas: operating experience; equipment replacement concerns; impact of fuel cycles and fuel bundle designs; future fuel handling systems.

Summaries of 500 words or less should be sent to:
Bill Knowles
General Electric Canada
107 Park Street North
Peterborough, Ontario
K9J 7B5
Tel. 705-748-7170 FAX 705-748-7076

Reminder

3rd International Conference on CANDU Maintenance

Toronto, Ontario
19 - 21 November 1995

The program includes technical sessions on many aspects of the operation and maintenance of CANDU nuclear power plants. Seventy papers on a wide range of topics, such as valve performance, fuel channel replacement, steam generator maintenance, environmental qualification, instrumentation and control and reliability, have been accepted for presentation. In addition there will be several **open forum** discussion sessions.

To register contact: Sylvie Caron
Canadian Nuclear Society
144 Front Street West,
Suite 725
Toronto, Ontario
M5J 2L7

Tel. 416-977-7620, ext 18 FAX 416-979-8356

A Half Century of Fission

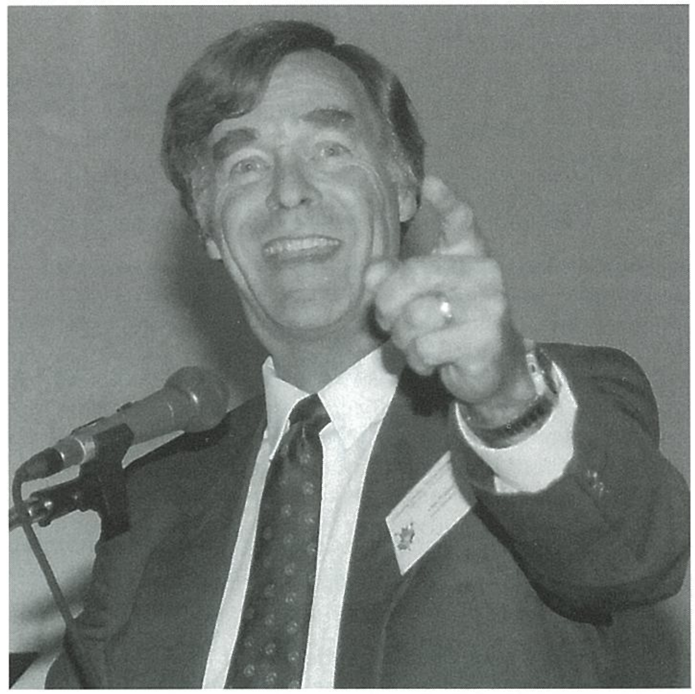
Over the weekend of August 4 to 6, 1995 lectures were given, a banquet held and exhibits and workshops conducted at Chalk River and Deep River to celebrate the 50th anniversary of the start-up of the ZEEP reactor in 1945. Under the title of *A Celebration of Canada's Nuclear Heritage* the events drew hundreds to the area as well as involving a high percentage of the workers at the Chalk River Laboratories of AECL and the residents of Deep River.

Organized by the Education and Public Affairs Committee of the Canadian Nuclear Society under the chairmanship of Aslam Lone, with sponsorship of many groups, the entire event was very successful.

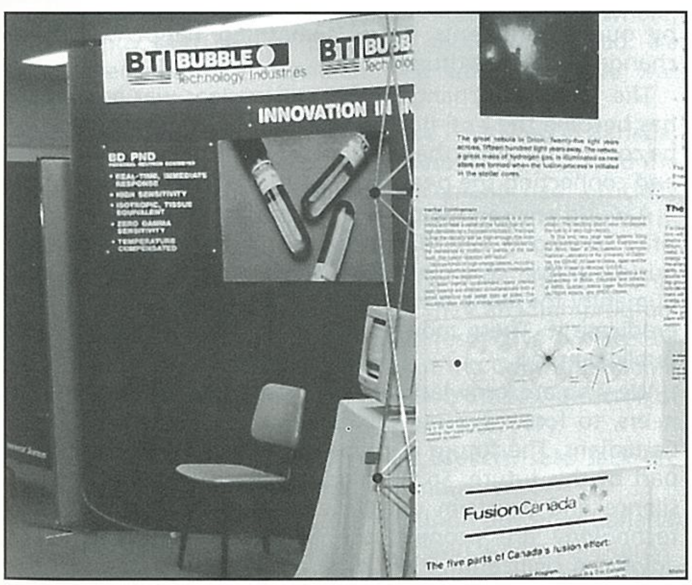
On Friday, August 4, an overflowing crowd in the library auditorium at CRL listened to the reminiscences of two former prominent members of the Canadian nuclear program and the predictions of a current leader. Ralph Green, former vice-president of AECL Research, gave a fascinating picture of the early days at Chalk River with emphasis on ZEEP. (See the lead article in this issue, *ZEEP, the Little Reactor that Could*.) He was followed by Paul Scholfield, former executive vice-president of GE Canada who spoke about the contributions made by manufacturers such as GE. They were followed by David Torgerson, AECL vice-president of research and product development who outlined some of the developments underway and planned. He noted, as an example, that a new design for the CANDU emergency cooling system had 90 percent fewer valves.

That evening over 250 guests filled a hall in Chalk River for a special "heritage" banquet. Four in the audience had been at Chalk River 60 years ago when ZEEP started up. Many others had joined the project over the next decade, which led to much sharing of memories.

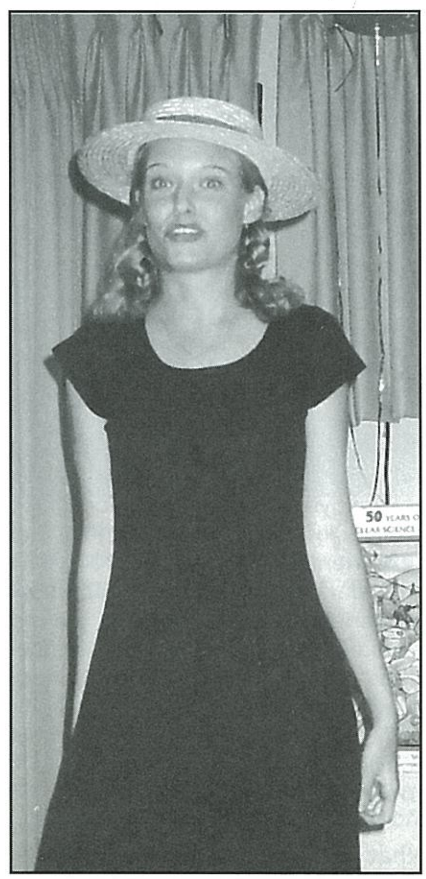
A young string trio played during dinner. Then one of the members, Meg Jones, sang a number of songs from the musical *Anne of Green Gables*. Her full, rich voice and animated presentation drew strong applause.



Alan Walter challenges the audience during his talk at the banquet during the Celebration of Canada's Nuclear Heritage August 4, 1995.



A view of two of the many exhibits displayed during the Celebration of Canada's Nuclear Heritage weekend.



Young singer Meg Jones was a hit at the Canada's Nuclear Heritage banquet at Chalk River, August 4, 1995.

Alan Waltar, the immediate past-president of the American Nuclear Society was the guest speaker. Alan presented a strong argument for the benefits of nuclear technology in an elegant, energetic and earnest manner that evoked thoughts of an evangelist preacher. "Does our science speak for itself?" he asked. "We are going to have to do it" he argued. "If the public really understood what we have to offer we would be considered saviours." When he suggested "there may be more support in Canada because you are a rational people", a number of looks were exchanged.

"When I look at the spectre of using up all the fossil fuels that took billions of years to create in just a few generations, I cry" he said. "We have something that is incredibly valuable. We must communicate that. It's up to us."

On the Saturday and Sunday, August 5 and 6, there were exhibits in the AECL Employee Development Centre (former Cockcroft school) in Deep River along with "hands-on" workshops which attracted good crowds. At noon a street was renamed "Brockhouse Way" in acknowledgement of the Nobel prize won by Dr. Bertrand Brockhouse for his work in neutron spectroscopy at Chalk River.

A month later, on September 5, the actual date of the start-up of ZEEP, a smaller celebration was held at which Terry Rummery, former president of AECL Research spoke on the need for scientific research.

Our obligations on the 50th Anniversary of Nuclear Fission in Canada

Ed. Note: *CNS President, Jerry Cuttler, prepared this note on the occasion of the Celebration of Canada's Nuclear Heritage, August 4-6, 1995.*

Jerry Cuttler
CNS President

We look back in wonder at the almost miraculous accomplishments of our pioneers, some of whom brought technology, skills and even heavy water from Europe. We recognize the first achievement of the fission chain reaction in Chicago in 1942 and acknowledge the help we received from the Americans to be the first outside the United States.

That started Canada on the development of the CANDU. We must be thankful for the skill and dedication and vision of our scientists and engineers, and for the faith and support of the Canadian government and the Ontario government.

We celebrate the success of 22 CANDU reactors operating in Canada and those operating and under construction abroad. We are proud of the 20 that last year supplied two-thirds of the electricity used in Ontario, of the record-breaking performance of Pickering unit 7, Point Lepreau, Wolsong and other CANDU units. Each new CANDU sale brings to Canada hundreds of millions of dollars of annual revenue and tens of thousands of jobs. It is just phenomenal for a country the size of Canada and the relatively small investment we have made.

But all is not well here. Canadians do not understand our technology and many are fearful of nuclear radiation. Students are being taught that this radiation is a carcinogen, and we all know how terrifying an illness cancer is.

Next year we will be celebrating the centennial of the discovery of nuclear radiation by Henri Becquerel. From our experience over the past 100 years we have mountains of real data on the effects of radiation on health. Based on this experience the industry used the model of threshold dose for radiation health protection. But the radiation health authorities have, in recent times, abandoned science and use the unsubstantiated liner dose-effect hypothesis, just to be extra safe. In doing this they have unwittingly given the anti-nuclear movement (and media) a basis for frightening the public.

Today's youth is tomorrow's government. It is not certain that any nuclear technology (including nuclear medicine and irradiation of food) will be tolerated, let alone supported, by our governments unless something happens now to change people's attitudes.

The time have changed. the anti-nuclear war movement has become the anti-nuclear power movement. It will soon be commemorating the bombing of Hiroshima and Nagasaki and connecting the peaceful uses to the military use.

A world environmental movement has arisen and unscientific ideologies are disseminated. Instead of embracing nuclear power as a clean, safe technology that will sustain humanity for many centuries these two movements seek to eradicate it. These movements now occupy the domain of public opinion.

We who are knowledgable have an obligation, to our pioneers, to foster our nuclear heritage for the benefit of all Canadians. The future is in the atom and Canada should be part of this future. So we must abandon our restraint and silence and proclaim our belief that nuclear science and technology are proper, safe and essential elements of advanced civilizations. We must declare our support in the task of preserving, enhancing and fully utilizing the bounty of the atom for the enduring benefit of humanity.

GENERAL news

Fusion Seminar

Dr. E. Velikhov gives keynote address to Fusion Seminar in Montreal, September 7, 1995.

The "Status and Prospects for Fusion Power Development" was the theme of this year's Fusion Seminar held in Montreal, September 7 and 8, 1995. More than 100 delegates attended the day and a half meeting, including 35 from outside Canada, which was followed by a visit to the Tokamak de Varennes of the Centre Canadien de Fusion Magnetique.

Money, or the lack thereof, was a major concern for several speakers outlining the programs in Canada, USA and internationally. Dr. Anne Davies. of the US Department of Energy, noted that significant cutbacks were expected in their fusion budget. This will require major re-direction of the program, she said, and added that input from all those in the fusion community and others will be sought.

Dr. E. Velikhov, chairman of the Council for the International Thermonuclear Experimental Reactor (ITER), was the invited keynote speaker. He commented that the financial difficulties Russia is facing will make it unlikely that his country will be able to contribute significantly to ITER. Nevertheless, Russia is still supporting participation in the ITER consortium. Despite problems in Russia and elsewhere, Dr. Velikhov said he felt that ITER should go ahead. He commented that the Canadian ITER siting initiative was "visionary".

In his report on the initiative to have ITER sited in Canada, Don Dautovich of Ontario Hydro Technologies, provided the good news that the Federal government had officially agreed to support a Canadian bid for the project (but without federal financial contribution).

Dr. David Jackson, Director of the Canadian National Fusion Program, gave an overview of the Canadian program followed by general pictures of their respective projects by Dr. Richard Bolton, Director General of the Centre Canadien de Fusion Magnetique (CCFM), and Bob Stasko, Director of Canadian Fusion Fuels Technology Project (CFFTP).

The Canadian program has three aspects, said Jackson; energy, science and technology, and industry:

energy - to establish the basis for fusion power in Canada;
science and technology - to gain access to international knowledge through excellent contributions;
industry - to develop and market Canadian industrial capabilities.

It has four components: CCFM, CFFTP, international, inertial confinement. Most of the work on the last item is carried out in universities.

Bolton reported that the Tokamak de Varennes (TdeV) is currently shutdown for upgrading, including the installation of a new diverter configuration. The revised machine will be known as TdeV 96. A further significant improvement is planned, under the acronym TdeV "M", and is targeted for the year 2000. It was noted that TdeV 96 is being funded out of the current budget. TdeV "M" will require new funding. In the discussion, David Jackson commented that in magnetic fusion work the machine is the experiment.

Stasko concisely reviewed the technologies pursued by CFFTP: isotope separation; tritium handling; remote handling; gas separation; materials development; plasma fuelling. He noted that the Darlington Tritium Facility had separated 13.5 kg. of tritium which is stored on titanium beds.

Both Bolton and Stasko referred to work their groups are doing for ITER.

Speakers from the USA outlined the work underway at MIT, General Atomics, Lawrence Livermore National Laboratory, Princeton Plasma Physics Laboratory, Oak Ridge National Laboratory, and other facilities. Dr. John Sorres of the University of Rochester gave the one paper on the

Paul Gierszewski of CFFTP is flanked by the winners of CFFTP Fellowships for 1994 and 1995 following his presentation of the awards at the Fusion Seminat in Montreal, September 7, 1995. On the left is David Novog, 1994 Fellow. David is a Ph.D. candidate at McMaster University, working on heat transfer correlations for water under high heat flux condition. On the right is Wade Zawalski 1995 Fellow who is in the Ph.D. program at the University of Saskachewan, operating the USask compact toroid injector and studying the interaction with STOR-M tokamak.
CFFTP has awarded nine fellowships since the inaugaration of the program in 19990. Each Fellowship consists of a stipend of $15,000 to the student or $10,000 to the university and is renewable.

nertial confinement approach to fusion, commenting that there had been good progress in that area, that much relevant information has now been declassified, and that there was a high probability of demonstrating net gain in less than 10 years.

Dr. P. Barabaschi of the ITER Joint Central Team provided a brief review of the proposed ITER design. The objectives, he noted, are: to demonstrate controlled ignition and burn; and, to demonstrate essential technologies. Dr. Charles Baker, leader of the US ITER Home Team, and Dr. S. Matsuda, leader of the Japanese ITER Home Team outlined the major design work underway in their two countries. There are four "Home Teams"; in Europe and Russia as well as the USA and Japan. ITER is a joint program of the USA, Japan, Russia and Europe. Canada is a participant with the European team.

Baker commented that the current estimated cost of ITER is $5.8 billion US$. He noted that it is being designed to be "site-able" in the area of any of the parties.

Despite the concerns about actual or potential budget cuts there was a generally optimistic attitude among the delegates and an obvious enthusiasm for the research and development underway.

Next fall, the large International Fusion Conference sponsored by the International Atomic Energy Agency will be held in Montreal .

AECB publishes new book on radiation

The Atomic Energy Control Board has published a 122 page book on radiation aimed at the general public.

Canada: Living with Radiation was written by three members of the AECB's advisory committees; David Myers and Peter Barry, formerly with AECL Chalk River Laboratories, and Bob Wilson, formerly with Ontario Hydro. Inspired by a similar publication produced by the National Radiological Protection Board of the UK, the authors have produced an easy-to-read book covering both natural and man-made sources of radiation, usage of radioactive materials and nuclear energy in general.

Accompanying the easy text are numerous illustrations and graphs. A glossary is included.

The book is also available in French under the title: *Canada: vivre avec le rayonnement.*

Canada: Living with Radiation or Canada: vivre avec le rayonnement is available through booksellers or from: Canada Communications Group - Publishing, Ottawa, Ontario, K1A 0S9, FAX 819-994-1498, for $12.95 (plus applicable taxes).

APPOINTMENTS

Ron Field has been appointed General Manager of Ontario Hydro Nuclear, replacing the retiring Don Anderson. Ron is the former Director of OHN's Finance and Business Services. According to Ron, OHN now must minimise distractions and focus on steady improvements in safety and operations in order to remain competitive. In particular, he cites disappointing Peer Reviews and the recent criticism by the AECB on operating procedures and processes. The distractions he refers to include the creation and breakup of ENCON, corporate restructuring, staff reductions and staff relocations to sites.

Irwin Itzkovitch, a former president of the Canadian Nuclear Society, has been appointed to the position of Senior Vice President, Technology, and also Director of the Noranda Technology Centre. Prior to his appointment, Dr. Itzkovitch was Director General of the Mineral Technology Branch at Natural Resources Canada.

Nuclear on the WEB

Everyone seems to be "going on the web", the World Wide Web of Internet, that is.

Atomic Energy of Canada Limited and the Atomic Energy Control Board have both recently announced the launching of Web pages while the Canadian Nuclear Society, through the efforts of the Golden Horseshoe Branch based at McMaster University, has been posting a Web page since earlier this year.

AECB

The AECB page is in both official languages and includes the Board's mission statement, a brief description of the agency's role, and ways to contact the AECB Office of Public Information. As well, Web surfers can browse through the electronic version of the AECB's Annual Report for 1994-95. AECB's page also offers a picture tour of the nuclear industry.

The AECB's Web page is at: http://www.gc.ca/aecb

AECL

AECL's opened its bilingual page on the Web server at the Chalk River Laboratories in August. The information provided will be updated on a continual basis.

The AECL page is at: http://www.aecl.ca

CNS

The CNS Web page is operated by members of the Golden Horseshoe Branch at McMaster University in Hamilton, Ontario and provides information about the CNS and nuclear technology.

The CNS / Golden Horseshoe web page is at: http://ece.eng.mcmaster.ca/cns.html

AECB board member dies

Dr. Robert Farvolden, distinguished professor emeritus at the University of Waterloo and a member of the five©member Atomic energy control Board since 1986, died, September 13, 1995. He was 67 years old.After receiving his doctorate from the University of Illinois in 1963, Dr. Farvolden came back to Canada in 1967 to teach in the geology department of the University of Western Ontario. In 1970 he moved to the University of Waterloo where he subsequently became chairman of the department and Dean of Science.

Donations in his memory may be made to the R. N. Farvolden Scholarship for Graduate Students, c/o Alumni Office, University of Waterloo.

Dr. Farvolden's passing leaves a vacancy on the AECB Board.

AECB reorganizes Materials Directorate

The Atomic Energy Control Board has announced the reorganization of its Directorate of Fuel Cycle and Materials Regulation.

Two former divisions have been dissolved: the Radioisotopes and Transportation Division and the Compliance and Laboratory Division.

Two new divisions have created: the **Standards and Services Division** and the **Materials Regulation Division**.

Heading up the new Standards and Services Division is **Ross Brown** who was director of the old RTD. **Mike Taylor**, formerly director of Power Reactor Division B, has been appointed as director of the new Materials Regulation Division. Former acting director of the old CLD, Elizabeth Greaves, has retired.

The Materials Regulation Division embraces the following sections: Industrial and Transportation Licensing; Medical and Accelerator Licensing; Radioisotope Licence Processing; and the four regional offices.

The Standards and Services Division will have two sections: Standards Development ad the Laboratory.

The Uranium Facilities Division under Tom Viglasky and the Waste and Impacts Division under Cait Maloney remain unchanged. Murray Duncan continues as the Director General of the directorate.

Nuclear on the WEB

AECB: http://www.gc.ca/aecb

AECL: http://www.aecl.ca

CNS/Golden Horseshoe :
http://ece.eng.mcmaster.ca/cns.html

Public Opposition in Oakville

Report on a public meeting on CANATOM's proposed low-level transfer station.

***Ed. Note:** The following is an abbreviated report based on an extensive one prepared by Jeremy Whitlock of AECL Sheridan Park who attended the meeting. Those wishing more information on the event should contact him.*

Background

CANATOM plans to operate a low-level radioactive waster transfer station in Oakville, Ontario. The facility is intended to receive mainly solid waste from hospitals, universities and industry, hold it for four to six weeks until a truck load is accumulated, and then ship it to Chalk River. CANATOM received a licence from the Atomic Energy Control Board in June 1995. No processing or repackaging would be done at the facility.

Two public meetings had been held previously, one by the Council of the Town of Oakville in January 1995, and one by the AECB prior to its licensing action.

A group called CORP (Citizens Organized for Responsible Process) organized a public meeting on November 2, 1995, co-sponsored by two locals of the CAW and several other smaller groups.

MEETING

About 240 people filled the high school auditorium to capacity. They were presented with a panel of "experts" consisting of: Dr. (Sister) Rosalie Bertell, a well-known critic who heads her own organization, the International Institute of Concern for Public Health; Norm Rubin of Energy Probe; David Donnelly of the Environmental Defence Fund, an environmental legal-aid group; and Irene Kock of Durham Nuclear Awareness, a group that has been protesting Pickering and Darlington. The media was well represented including CITY and CFTO TV stations.

PRESENTATIONS

Dr. Bertell brought greetings from U of T professor Dr. Ursula Franklin, who sent two sentiments: "NO", a democratic process had not been followed (despite the two previous public meetings) and, "YES", people should be concerned.

Bertell referenced the nuclear weapons industry (despite the absence of such activity in Canada and the complete irrelevance to the proposed facility). She claimed that only about 5% of the waste would be medical (whereas by far the majority of the waste will be medical). She claimed that the committed dose that someone would receive if they inhaled all of the Phosphorous 32 in a 45 gallon drum with a maximum concentration was 140 mSv which she compared with the limit of 20 mSv for atomic radiation workers (conveniently overlooking that this was a theoretical calculation with almost zero possibility).

Irene Kock's main theme was the lack of credibility of the AECB. She spoke about past tritium releases into Lake Ontario (from Pickering NGS) and the fact that Chalk River does not have a decommissioning plan.

Norm Rubin echoed Kock's diatribe against the AECB and expanded on her account of the tritium spills. He noted the recommendation from an Ontario environmental advisory committee that the standard for tritium in drinking water should be reduced from 4000 Bq/L to 20 Bq/L, while ignoring the counter advice from scientific bodies and the resulting non-action by the provincial government. The effect was to leave the impression that the limits (and by implication the releases) were 200 times higher than the "safe" level.

David Connelly began by passing around a jar for donations. Regardless that he gave no explanation most in the audience immediately reached for their wallet. Later he commented that the money would go to the Environmental Defence Fund.

During the question period reference was made to a food storage facility in the same complex as CANATOM's (but no mention of the two other AECB licensed activities).

Someone from Port Hope gave a long account of the movement there to stop the siting of a low level waste depository.

One lonely member of the audience spoke in favour of the CANATOM facility but was shouted down, especially when he tried to note the lack of scientific credentials of most of the panel members.

It was clear from the meeting that the nuclear industry and the AECB have little credibility, at least with that group of citizens. There was a perceived lack of public consultation, despite the public meetings held by the Town of Oakville and the AECB. And there was complete ignorance of the

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Problems at Point Lepreau

Just as it was in the start-up phase after its major six months shutdown the Point Lepreau generating station suffered a significant failure that will take several weeks to overcome. The long shutdown had been primarily to relocate (SLAR) the spacers between the pressure tubes and calandria tubes.

As the primary pumps were being started up on October 6 high vibration was detected on Pump #1. Subsequent inspection showed that the connecting shaft between the motor and pump had failed.

Pieces of wood were found in the pump inlet. It was determined that a wooden nozzle cover that had been placed inside the boiler inlet during maintenance had been left inside. When the pump was started the cover was drawn into the pump suction and pieces of it into the impeller, causing the vibration. This led to failure of the seal and subsequently to overheating failure of the shaft.

Much of the debris from the cover was deposited in the inlet header requiring it to be cut open. The 95 fuel channels in that quadrant of the system will be back-flushed.

At the time of writing it was hoped to have the clean-up and repair work completed so that the plant could be started -up by early December.

BOOK Review

NUCLEAR PURSUITS
- The Scientific Biography of Wilfred Bennet Lewis

Reviewed by Fred Boyd

by Ruth Fawcett
McGill-Queen's University Press

For over two decades Dr. W. B. Lewis was the central figure in Canada's nuclear program. From his appointment as head of the Chalk River Project in 1946, as the successor to Dr. John Cockcroft, until the late 1960s Lewis was the driving force behind the research and development that led to the CANDU reactor concept. For many he is considered as the "father" of CANDU.

In this easy to read biography Ruth Fawcett provides a picture of Lewis' early days at the Cavendish Laboratory at Cambridge University, his involvement in the development of radar during World War II, and further insights into his role at Chalk River.

After obtaining his Ph.D. at Cambridge in 1934, Lewis stayed on at the Cavendish Laboratory. There he tended to concentrate on developing electronic equipment such as counters, control systems for a cyclotron, and wireless applications.In the spring of 1939 just before the war began, Lewis, at the age of 31, was put in charge of the radar research establishment at Bawdsey. This eventually evolved into the Telecommunications Research Establishment at Malvern. There he led the scientific team that developed the radar systems so critical to Britain's survival in W.W. II.

In 1946 Sir John Cockcroft, with whom Lewis had worked and who had come to Canada in 1943 to head the Montreal Laboratory, was recalled to Britain to head up the UK nuclear program. He recommended Lewis as his successor.

Lewis arrived at Chalk River in September 1946 and quickly displayed the energy, intensity and wide-ranging knowledge that became his hallmark, As Fawcett writes, "at times it appeared that Lewis was more knowledgable about [a topic] than the scientists working on it".

Fawcett reviews Lewis' dominant role in the exciting work at Chalk River during the 1950s and the beginning of the nuclear power program with NPD. Initially against the use of pressure tubes (largely because of the neutron absorption since he was almost obsessed with "neutron economy") Lewis became convinced of the advantages and in 1957 led the decision to stop the NPD project to redesign the reactor with pressure tubes.

Perhaps the most revealing chapter concerns ING - the Intense Neutron Generator - which Lewis championed in the 1960s. The ING concept was to use an accelerator to drive protons into a lead-bismuth target which would produce fast neutrons by spallation. These would be slowed down in a surrounding tank of heavy water. The arrangement had the potential to produce neutron fluxes much higher than any existing or planned reactor. Unfortunately, Lewis overlooked the political problems of funding such a large project and, in particular, ignored the need to gain the support of the university community. Apparently jealous of the large funding already going to Chalk River, the university deans collectively opposed ING, giving the government an excuse to do nothing and ING died.

In the late 1960s Lewis role was diminishing. In 1969 he became part of the AECL head office organization with no line responsibilities. Following his retirement in 1973 he spent several years as a "distinguished professor of science" at Queen's University.

He developed Alzheimer's disease in 1982 and spent most of the next five years, until his death in January 1987, in the Deep River hospital.

As well as his leadership at Chalk River, Lewis was elected president of the American Nuclear Society, the only non-USA person to do so, was a member of the UN Scientific Advisory Committee set up in conjunction with the 1955 "Atoms for Peace" conference, and, subsequently, the Scientific Advisory Committee of the International Atomic Energy Agency. In 1966 he was granted the first Outstanding Achievement Award of the Public Service of Canada. He received the Atoms for Peace Award In 1967 and the Enrico Fermi Award in 1982.

Some indication of Lewis prodigious output is Fawcett's listing of his publications - 23 in the UK before coming to Canada; 116 "Director's Lectures"; 140 "Director's Memoranda"; 39 "Director's Reports"; 44 AECL reports and 15 papers after retiring.

Although Fawcett does not provide much insight into the personality of W. B. Lewis she does chronicle well his central role in the critical early years of Canada's nuclear program.

For anyone interested in the Canadian nuclear program this book should be required reading.

GENERAL news

Public Opposition in Oakville

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nature of the wastes and its origins (mostly from very beneficial nuclear medicine procedures). Added to that was the issue of possible loss of property values. Underlying all the concerns appeared to be a basic fear of radiation.

As an editorial comment, it is evident that when a relatively innocuous facility such as that proposed by CANATOM can generate such a negative reaction, the nuclear industry still has a long way to go to win over the public. It is also sad that with so many members of AECL Sheridan Park living in the vicinity so few bothered to attend this meeting to try to counter the extreme statements presented.

BOOK Review

BEING DIGITAL

Reviewed by Keith Weaver

by Nicholas Negroponte
Alfred A. Knopf, New York, 1995

The livelihood of many of the people who read the CNS Bulletin is associated with a particular kind of nuclear reactor. That reactor system exists because a few people were instrumental in bringing it into existence. There are many other instances of products, services and functions in the world that owe their existence to one person or a few people. Without such people, we would all live in a state of much greater intellectual and physical impoverishment. In other words, the world needs visionaries.

There are visionaries who have been at the same time the instruments by which their visions took physical form. There are also visionaries who foresaw but did not take part in physical creation. On the other hand, for every visionary whose ideas and their physical embodiments have changed the lives of succeeding generations, there are cartloads of people who are seen as nuts, kooks and cranks, and there are unknown and possibly greater numbers who have now vanished from the record.

Nicholas Negroponte cannot be dismissed out of hand. He is a respected academic who has pursued his dream tenaciously and with success. And since he is writing on a subject that has already seen vast, almost revolutionary changes that have had significant impacts on our lives already, he deserves a hearing.

Being Digital puts forward the case that the world and the people in it are quickly heading toward a digital future. The capabilities of the tools and equipment that this future will unveil have, Negroponte claims, the power to transform the way personal, social and institutional structures are understood and the way they will function. Things are going to change dramatically, in every sphere. The characteristics of the "digital age" that will cause it to prevail over all obstacles are, according to Negroponte, its ability to decentralize, to globalize, to harmonize and to empower.

At the heart of the thesis appears to be our almost emerged ability to transfer and manipulate digitized information at astonishing rates. What seems to stand between where we are now and the coming "digital age" (if I am interpreting correctly) is our as yet insufficient capability, or our failure, to incorporate this new found technology into our lives in some systematic way, thereby liberating its promise. What this statement means in more concrete terms is spelled out by Negroponte for a very large number of potential applications. Most of these are, or sound, "futuristic".

For example, there is a crying need to restructure the interfaces between people and almost all our appliances and equipment. Computers are an obvious case. A personal computer, once it incorporates competent voice recognition capability, can be expected to become a far more versatile tool, and to become integrated to a much greater extent into our lives. This extends beyond just making the job of, say, preparing book reviews easier. A computer can become a slave, or an "agent". If such a computer can recognize whether you are in the room, whether you are looking at it or intending to communicate with it, what mood you are in, what your interests are at the moment, and so on, then it becomes more than just an unintelligent thing, with an associated obtuse interface across which you can transmit your intentions only very slowly. From being a valuable tool, it could become a very valuable or even an indispensable tool.

The combination of having all information digitized and being able to transmit that information at vastly increased rates, will generate at least the potential to transform other utilitarian and entertainment appliances.

For example, a VCR could build up a profile of what you are interested in, scan movie and news outlets, surf the net for current information of value or of interest to you, and have it ready to view or to consider when you want to do so. Furthermore, with large data transmission rates, it could do all this at stupendous speeds. The Internet (or its' evolutionary successor) is seen to be an essential element in all this, providing a window on the world with an unparalleled view.

Another example. You have completed something earlier than expected, or you have learned that an appointment or a need to be somewhere tomorrow at some specific time is now less urgent. You reset your alarm for half an hour later. The clock can communicate with your coffee maker, your electronic desk calendar, and anything else that is geared to some prearranged timing of events. When you awake, half and hour later than usual, your coffee is not a half hour old and terrible, you have not run afoul of other arrangements, and other schedules that may have been affected have already been rearranged.

Further examples. Your refrigerator can sense that the milk or butter is low. It communicates with your car which reminds you on the way home to stop for these things. Your daily newspaper may have been printed as an edition of one copy. The physical form of the newspaper is an advanced slate on which items that are of interest or of importance to you have been laid out electronically. The information used in this layout comes from a satellite and has been sorted, edited and presented by circuitry built into the fabric of the "paper" itself. When you have finished reading your paper (or optionally, when you have finished listening to it read you the news) you may not throw it away, but rather just "erase" or update it.

This "futuristic" outlook on what tomorrow holds may derive from a fixation, an infatuation, or some other form of intellectual commitment to the equipment that may lead to a digital world. At one point in the book, the author enters into a discussion of fax machines. The apparent vehemence of this discussion may be telling. He says that fax machines are a step backward. They derive from Japanese culture and orthography, which does not lend itself easily to being rendered into ASCII or some such format. Hence, for the Japanese, fax machines are a natural way to expedite business. In a digital world, they are anathema and retrograde.

The case made by the author against them is somewhat surprising in its' suddenness and in its vehemence. Is he protesting too much because something has successfully gone against the digital grain?

Some readers may expect the present reviewer to burst through the civilized text at this point saying "What a load of crap!" But in fact there is nothing wrong with someone expressing a vision of the future, no matter how difficult it is to accept such a vision at present, and no matter how unlikely it all may seem. What Negroponte's book is really presenting is the first phase of a brainstorming session. The danger is that nerds, special pleaders, naive optimists and unbridled spin doctors will swallow it all whole, or accept it all without question as though it were a description of something that is already, if effect, a fact. It is at this point that myth breaks into full gallop, and, Abraham Lincoln notwithstanding, the hyped drumbeat repetition of the myth makes it very difficult for people to determine where the truth actually lies. Therefore, it is important not simply to accept these imaginative constructions at face value, as would an ingenue, nor to dismiss them all out of hand. Certainly, there is a real need to cut down, well before their prime, the mindless repetitions of the myth, with all their gushing enthusiasm and slavering gullibility. The next step in the brainstorming is the examination of ideas under a more critical light, with a view to determining which ones can be elaborated and used, and which are just lighter-than-air fantasies. This step is by far the most demanding, and it can bring forth the true benefactors of humanity, those people who can buck the trends of conventional wisdom and received opinion, and demonstrate that something is indeed practical even though it may be new and unaccustomed.

It's hard to deny that some of Negroponte's ideas appear to be "off the wall", and the jury may be out for a long time on them. In the meantime, what to say about *Being Digital*?

For me, there are some problems underlying the way some of the notions are presented. At one point, the author is talking about the way in which various information channels (AM, FM, television, cable, HDTV and so on) are currently used and how the advent of digital transmission of information could change all that.

One example used is the daily TV weather report. There is no need to retain the current presentation of the weather, Negroponte says. In future, the digital data representing the upcoming weather could be transmitted in such a form that the viewer would be free to have it presented in any format he or she wishes: as satellite images, as still charts and graphs, as a simple narrative, or as a presentation by one's favourite Disney character (!!!). On the other hand, it will also be possible (once again according to Negroponte) to download the weather model used to generate this data into your own TV set. There, a computer will run the model independently of any weather bureau and you can produce your own weather prediction, once again to be displayed when and as you choose. Apart from the cost and difficulty of compressing twin Crays (on which current atmospheric circulation models run) into home television sets, there is a rather cavalier notion here that any Joe can run a weather model and get sensible information out of it. No expertise is needed. No skill at interpretation is required. This strikes me as naive and uninformed. Is humankind's hard-won acquisition of knowledge and expertise discounted with simular abandon elsewhere as well?

A second example is the impression given by the author that the difficulty experienced by students under current education schemes is an artifact; learning does not have to be this difficult, and ready access to lots of computing power and the Internet (or, once again, its successor) can change all that. Learning can become exciting and interesting, with much of the slog removed. In particular, at one point the author figures our current education systems, and their demands to ingest and retain large amounts of useless fact, and he blames this requirement as a source of the effort that today's students experience in learning, effort which he appears to regard as unnecessary and spurious. This notion is probably one of the present day's most pernicious load of male bovine droppings. For anyone to think that learning can be made inherently easy, simple or "fun" is, to me, incomprehensible. To think that children who are given computers will immediately use them for academic advancement, no matter how interesting the software, is little more than the fevered ravings of a confirmed nephelococcygiac. Here we have true Cloud-Cuckoo-Land.

Still on the education theme, I suggest a yet more sobering thought. Bring to mind any time you have been exposed to someone who has undoubtedly mastered a "method" but has command of few facts. Such people may be good at negotiating the sale of rolls of wallpaper. Their ability to hot-wire computer peripherals may be legendary. Tthey may have few rivals in their skill at gutting annual reports. But my experience of such people is that they often have difficulty discussing a normal range of day-to-day topics. They are frequently at sea when faced with a page chose arbitrarily in an atlas. They can generally sidelined by those conversations where odd facts and snippets of information are tossed into the discussion at random, adding leaven, interest and diversion. In these sorts of situations, I find that they are a dead loss. In general daily interactions, people who only know "method" and don't know "things' become as obtuse, doltish, unresponsive and dead as any stone. Street slang would brand them as "geeks". In fact, they become much like computers: superb at their narrowly defined tasks, useless and uninteresting elsewhere.

There are things to learn from *Being Digital*. Negroponte presents some unusual and challenging views of possible futures. Some of it, in my humble opinion, is gruff. After reading the book, perhaps a more interesting topic for reflection is the role of the modern day visionary. What is his or her effect upon the throngs of uncritical "tabulae rasae"? It is the effect of the information age, to make people less critical, and ever more blinkered and credulous? Are our necessary visionaries bing turned into vulgar prophets and folk heroes? Are their visions being degraded to the status of misleading mantric statements of dogma, instead of being considered as interesting possibilities which should be examined critically for the value in them?

CALENDAR

1995

October 29 - November 2
ANS Winter Meeting
San Francisco, CA
contact: ANS office
Chicago, IL
Tel: 708-579-8258

November 6 - 8
Role of Reactor Physics in CANDU Power Plant Engineering (course)
Toronto, ON
contact: Sylvie Caron
CNS office
Tel: 416-977-7620
Fax: 416-979-8356

November 6 - 10
Reliability and Maintenance of Computerized Safety Safety Systems
Vienna, Austria
contact: Ms. S.L. Boyd
AECL Ottawa
Tel: 613-237-3270

November 19 - 21
3rd Conference on CANDU Maintenance
Toronto, ON
contact: Tim Andreef
Ontario Hydro
Tel: 416-595-3217
Fax: 416-592-7111

November 26 - 30
International Conference on Probabilistic Safety Assessment
Seoul, Korea
contact: Dr. Chang K. Park
Korea Atomic Energy Research Institute
Taejon, Korea
Fax: 42-861-2574

November 27 - 30
Nuclear Plant Life Management and Extension
Nice, France
contact: Phillippe Verdoni
Framatome
Paris, France
Fax: 33-1-47 96 01 02

1996

February ? ?
CNA/CNS Winter Seminar
Ottawa, ON
contact: Sylvie Caron
CNA/CNS office
Toronto, ON
Tel: 416-977-6152 ext18

February ??
Plutonium Disposition with CANDU
Ottawa, ON
contact: John Luxat
Ontario Hydro
Toronto, ON
Tel: 416-592-4067

March 10 - 14
ASME/JSME ICONE-4
Louisana, USA
contact: Dr. Howard Chung
Argonne National Laboratory
Chicago, IL
Tel: 708-252-6159
Fax: 708-252-4780

March 15 - 16
CNA/CNS Student Conference
Ottawa, ON
contact: Mohammed Lamari
Carleton University
Ottawa, ON
Tel: 613-788-2600 ext 1760

March 25 29
Nuclear Industry Exhibition
Beijing, China
contact: Xu Honggui
Chinese Nuclear Society
Beijing, China
Fax: 86-1-852-7188

April ? ?
Conference on CANDU Fuel Handling
Location TBA
contact: Ron Mansfield
Mississauga, ON
Tel: 905-823-2624

May 6 - 8
ANS Topical Meeting on Nuclear Plant I and C and Human-Machine Interface
University Park, PA
contact: Dr. R.M. Edwards
Penn State University
Tel: 814-865-0037
Fax: 814-865-8499

1996 *continued*

May ? ?
International Conference on Non-Proliferation and Safeguards of Nuclear Materials in Russia
Moscow, Russia
contact: Sergei Kushnarev
Kurchatov Institute
Moscow, Russia
Fax: No. 7 - 095-196-2073

June 9 - 12
CNA/CNS Annual Conference
New Brunswick
contact: Sylvie Caron
CNA/CNS office
Toronto, ON
Tel: 416-977-6152 ext18
Fax: 416-979-8356

June 9 - 12
Canadian Radiation Protection Association Annual Meeting
Trois Rivières, PQ
contact: Michel Rhéaume
Centrale Nuclieare Gentilly
Gentilly, PQ
Tel: 819-298-5252
Fax: 819-298-5039

July 21 - 26
ASME Presre Vessel Conference
Montreal. PQ
contact: Dr. R.C. Gwaltney
Oak Ridge National Lab.
Oak Ridge, TN
Fax: 615-574-0740
e-mail: rcg@ornl.gov

August 18 - 24
SPECTRUM '96 – ANS International Topical Meeting on Nuclear and Hazardous Waste Management
Seattle, WA
contact: K.L. Skelly
Richland, WA
Tel: 509-376-3931
Fax: 509-372-3777

September 16 - 19
Deep Geologic Disposal of Radioactive Waste
Winnipeg, MB
contact: M.M. Ohta
AECL Reasearch
WL Pinawa, Manitoba
Tel: 204-345-8625 ext 201
Fax: 204-345-8868

September ? ?
5th International Conference on Numerical Methods in Nuclear Engineering
Montréal, Québec
contact: Hong Huynh
Tel: 514-392-5614

September 29 - October 2
Canadian Society for Chemical Engineering Annual Conference
Kingston, ON
contact: Dr. H.W. Bonin
RMC
Kingston, ON
Tel: 613-541-6613

October 20 - 25
10th Pacific Basin Nuclear Confernece
Kobe, Japan
contact: 10-PBNC
Atomic Energy Society of Japan
Tokyo, Japan
Fax: 81-3-3581-6128

September ? ?
5th International Conference on Simulation Methods in Nuclear Engineering
Montreal, Quebec
contact: Raymond Leung
Ontario Hydro
Tel: 416-592-8624
Fax: 416-592-4930

1997

March 23 - 26
Advances in Fuel management
Myrtle Beach, SC
contact: Dr. Paul Turinsky
North Carolina State Univ.
Rawleigh, NC
Fax: 919-515-5115
e-mail: turinsky@eos.ncsu.edu

April 14 - 18
5th International Topical Meeting on Nuclear Thermal Hydraulics, Operations and Safety
Beijing, China
contact: Ken Talbot
Bruce NGD 'A'
Tiverton, ON
Tel: 519-361-2673

August 17 - 21
International Conference on Neutron Scattering
Toronto, ON
contact: Dr. W. Buyers
AECL Chalk River Lab.
Chalk River, ON
Tel: 613-584-3311
Fax: 613-584-1849

1998

May 3 - 8
11th Pacific Basin Nuclear Conference
Banff, Alberta
contact: Ed Price
AECL Sheridan
Tel: 905-823-9040

THE DARKER SIDE

by George Bauer

I don't often eat at *The Proven Mick*. This is an apparently down at heel, vaguely Irish pub clinging to life on the verges of Yorkville and is a favourite haunt of a particular group of incomprehensible denizens of Hazelton Avenue. Now, all the denizens of Hazelton Avenue are incomprehensible. This has been the case ever since that day back in the sixties when the police threw a few handsful (orthographical challenges, any-one?) of old syringes into the gutter, and blew up a hepatitis scare so that they could close *The Riverboat*. (Don't ask me why they did this. I was an earnest student at the time, a mere youth, meaning that I had only just outgrown my Flash Gordon costume, could reliably spell "Pigs!" and "Lysergic Acid" but not much else and spent a lot of my spare time (i.e. most of the day and all night) someplace. My more intellectual side was characterized by hair down to here, fascination with tight jeans up to there and a budgeting procedure that Ontario Hydro later adopted - because of its simplicity, you see; spend all the money you have and then start spending everybody else's.) Coming back to the syringes, however, there was a rumour that it all had something to do with Fred Gardiner, but that he became disillusioned and built an expressway instead. (A restaurant called "Fred's Not Here" was opened recently in an attempt to recapture the spirit of that age. It worked. Everybody soon realized that Fred was indeed not here. Too bad they hadn't called their restaurant "The Expressway's Not Here".)

But I digress. Back to the particular group of incomprehensible Yorkville denizens. Once garbed in their downscale threads and skids, they would hop their back fences and sneak through the gloom to *The Riverboat*, there to join us, the students, the real people. All this is gone now and The *Proven Mick* is but a faint reflection of what once was. As I say, I don't often eat here. And please don't confuse *The Proven Mick* with *The Mövenpick*. The latter is a block and a half away in a precinct populated by floppy-brimmed pastel sun bonnets, the Wildwood of Bloor and Avenue Road, where everything begins with a "c": calamari, chardonnay, creme fraiche, Camus, choucroute, cabernet, Chez Charles (Chateau des Cheveux), camembert, chaise longue, capers, cats, caftans and Chicklets. It's been more than four years since the last human was cited here, and the region is now home to flocks of Musical Goers, tourists called Blanche and Miles, the dimensions of whose backsides and wallets, respectively, are measured in axe handles. Besides, "mövenpick" has something to do with seagulls (pronounced "seegles") and singe we are about eight hundred miles from anything that could honestly be called a sea, we really ought to be referring to them as lakegulls (pronounced "lagles").

So I don't eat there.

To get back to my main rant, I rarely eat at *The Proven Mick* either.

This day, this fateful October day, I did. My lunch was a plateful of liquid fat swimming in sausages and hash browns, washed down and held there against its will by two pints of Creemore. The day was fine. A clear sky swept by high thin cloud flooded the earth with a golden liquid light that made it impossible to miss the passage of a four-and-a-half axe handler as it rumbled tectonically past the open door. It was swathed in white, knee-high jogging pants that were too tight. They didn't fit. A renewed struggle erupted between my lunch and the Creemore. Recent events all at once fused, blended, revealing a new and unwelcome panorama of meaning. Long used words, old and trusted friends, waved their reluctant farewells, and I now realized they had been mortally struck. Hitherto serviceable notions were now exposed as empty husks, about to be blasted and swept aside by a bleak wind. In the midst of this epiphanic nightmare, I suddenly realized that the world would never be the same again.

Our entire notion of demonstration, of proof, had been altered. Nobody would ever speak again with conviction. Nobody could ever again claim to be fit, because the word had been drained of its essence. Following hard on the heels of this sudden awareness, came the realization that the nuclear industry would take a particularly heavy hit. Examples swam quickly into view.

The years of work that had been poured into formulating quidelines to determine whether pressure tubes are fit for service, was now seen to have been wasted. These documents would have to be discarded without a glance back. End fittings would all need to be inspected without delay, and most likely replaced. Glove boxes would become history; they would all be torn out and junked before month's end.

I spared a moment for the individual tragedies that would quickly surface. Ellwood Glover would need to change his name and identity, and perhaps be forced to flee to a new city and begin afresh. In an evident fit of despair, Ted Turner has sold his entire communications empire. Numerous manufacturing concerns would rapidly spiral into bankruptcy, since their main products, gloves, would be shunned and no longer of value. Canada itself, I reflected, and all other cold climate lands, would have to revert to the use of mittens. The list formed unbidden in my head, and I had to break off the train of thought forcibly, fearing a migraine.

The unavoidable fact, witnessed by millions of critical viewers, scrutinized by the keenest minds available, was that the glove did not fit. The logical conclusions extending from this salient and unassailable fact, drawn by a pool o f the most trenchant legal intelligence, and scrupulously examined in its every aspect for days, (well, for four hours anyway) now could not be avoided.

Our world has been changed. The glove does not fit. O.J. is not guilty.

CNS Council • Conseil de la SNC

1995-1996
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