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DE LA SOCIÉTÉ NUCLÉAIRE CANADIENNE

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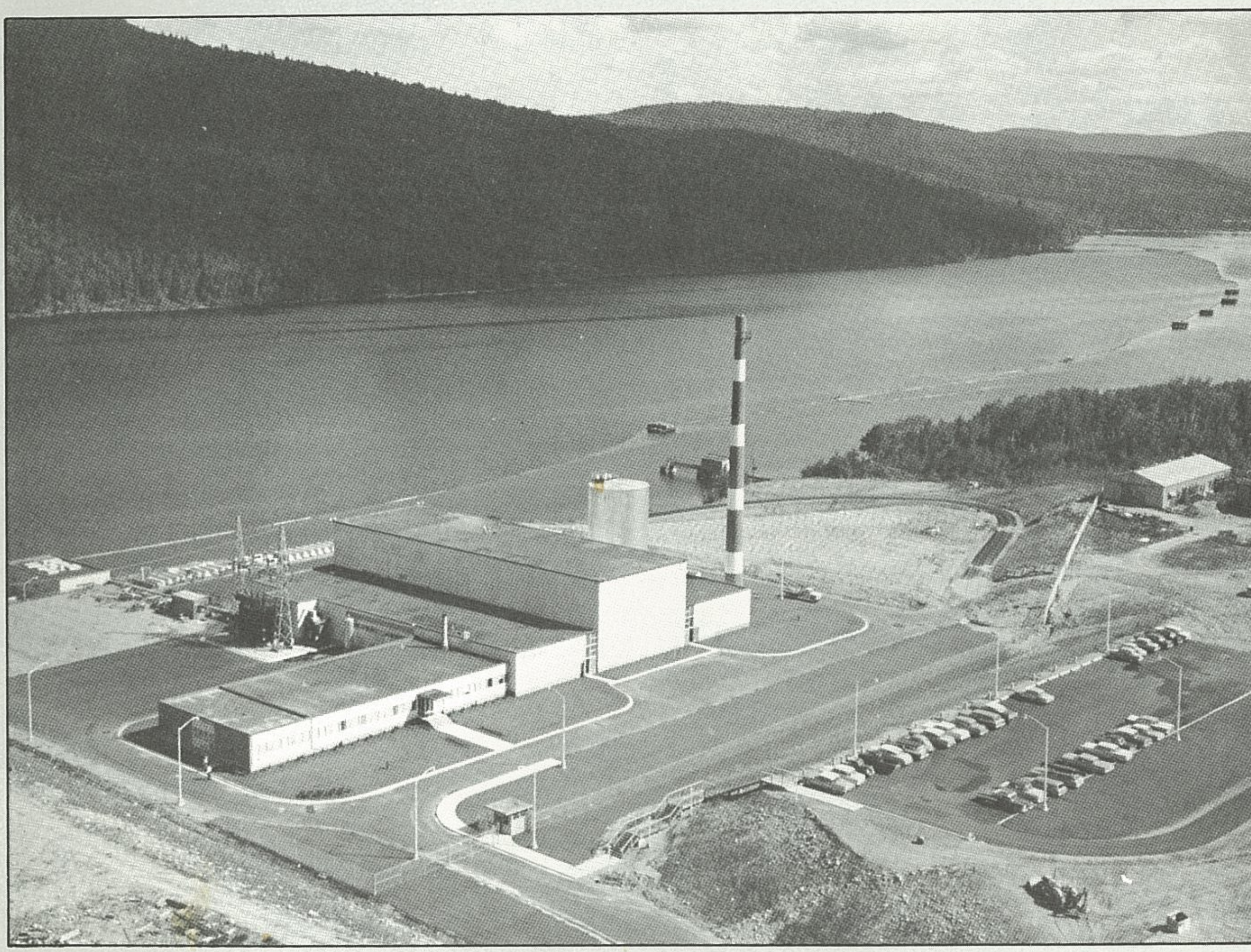

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We lead off this issue with a personal reminiscence of NPD (in lieu of an editorial!) since this is the 30th anniversary of the start-up of Canada's first nuclear power station.

This is followed by an interesting insight into the nuclear debate by Jim Weller and three "meaty" articles – on regulation and on CANDU restoration and improvement.

We have another historical note – on Madame Curie – news of members – and the full program for the 13th CNS annual conference.

As always, your comments are welcome.

Cover photo

An aerial view of NPD, with the Ottawa river in the background, taken in 1962, the year the station began operation.

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CNS provides Canadians interested in nuclear energy with a forum for technical discussion. For membership information, contact the CNS office, a member of the Council, or local branch executive. Membership fee is $55.00 annually, $30.00 to retirees, $20.00 to students.

La SNC procure aux Canadiens intéressés à l'énergie nucléaire un forum où ils peuvent participer à des discussions de nature technique. Pour tous renseignements concernant les inscriptions, veuillez bien entrer en contact avec le bureau de la SNC, les membres du Conseil ou les responsables locaux. La cotisation annuelle est de 55.00 $, 30.00 $ pour les retraités, et 20.00 $ pour les étudiants.

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NPD - A Beginning

by Fred Boyd

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

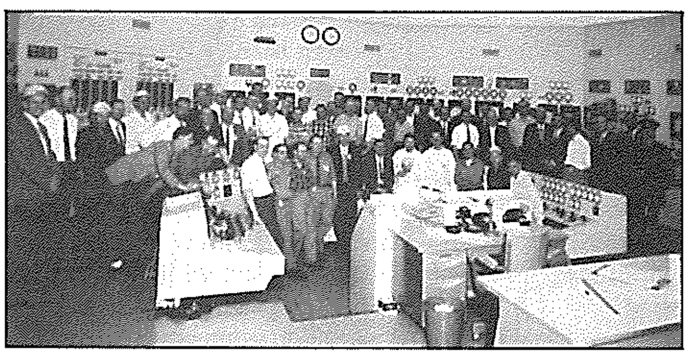
At 2:40 a.m., the morning of April 11, 1962, with about thirty intensively interested onlookers, the neutron counters took off, indicating that the self-sustaining chain reaction had begun.

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

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

NPD was a small plant - rated at only 20 MWe - but it pioneered most of the distinctive features of CANDU reactors - pressure tubes surrounded by calandria tubes in a horizontal configuration; pressurized heavy water coolant; heavy water moderator; natural uranium fuel using UO_2 in short bundles of pencils; automatic control.

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



Scene in NPD control room at start-up 2:40 a.m. April 11, 1962.

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

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

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

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

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

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

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

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

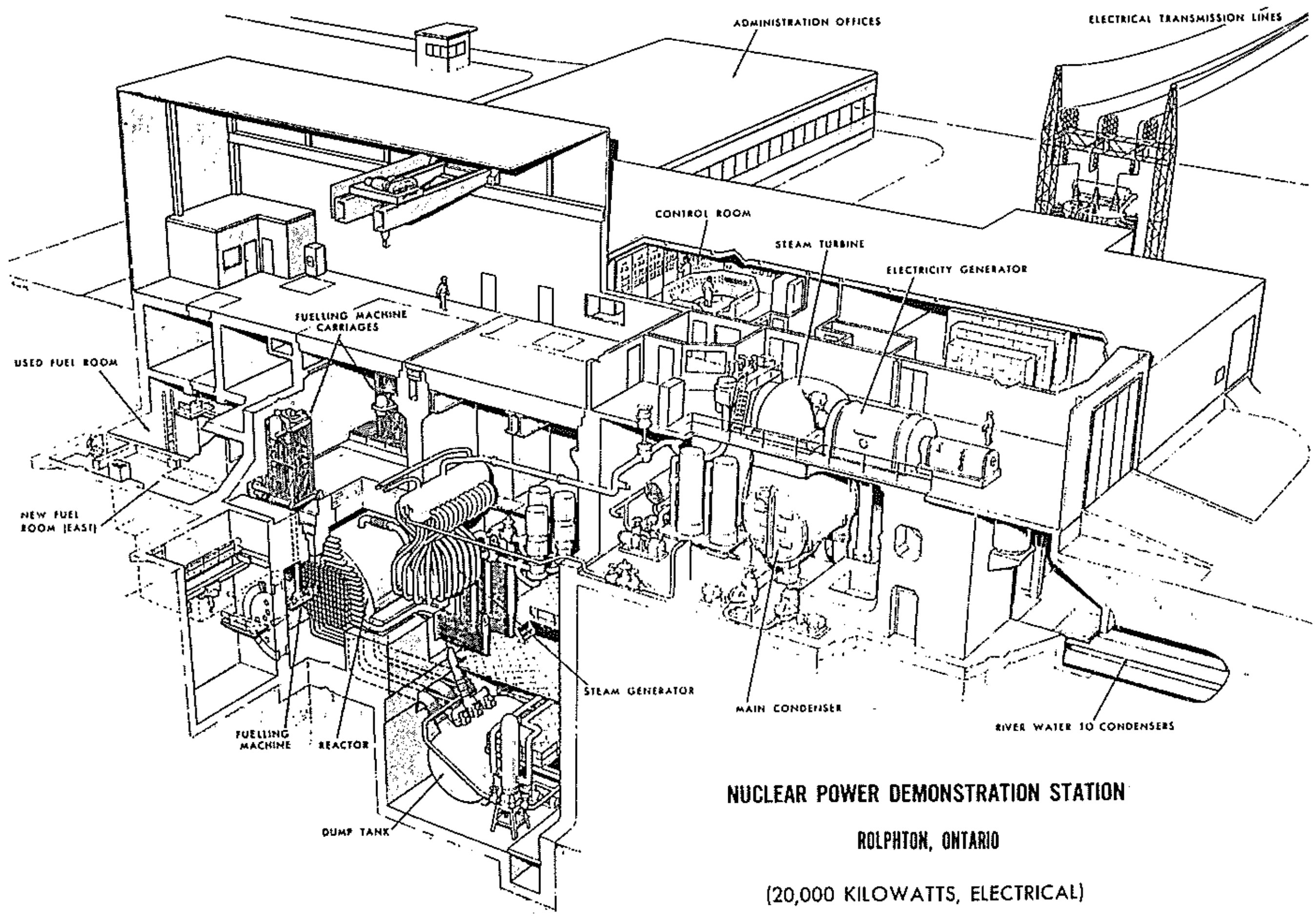
Many of the designers were involved in the installation and commissioning of the equipment or systems they had designed. This provided very effective and rapid "feed-back" which, unfortunately, was partially lost when the design of the next station – Douglas Point – was assigned to the newly created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

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

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

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

Bill Lawson announces first power from NPD, June 4, 1962.



NUCLEAR POWER DEMONSTRATION STATION

ROLPHTON, ONTARIO

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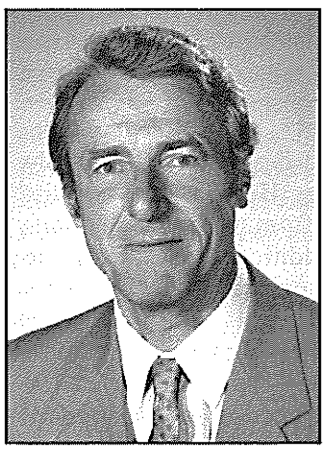
The Nuclear Debate

Observations on evolution of the nuclear debate – and lessons from it that might brighten the future

By Jim Weller

Ed. Note: *For over two decades, until his retirement last fall, Jim Weller was at the centre of the Canadian nuclear scene, as General Manager of the Canadian Nuclear Association and as one of the founders of the CNS.*

We feel that everyone concerned about an appropriate role for nuclear energy can profit from his insightful observations on the nuclear debate in this country.



CNA headquarters provided a unique vantage point from which to observe the evolution and moods of the so-called nuclear debate over two decades from August '71 to September '91. Retirement from CNA provides an opportunity to reflect on the observations and what they might imply for the future.

Throughout the period press clippings flowed daily over the desk, sometimes deluging it. Countless meetings, including the CNA board meetings (as secretary), provided frequent contact with key players in the industry. Briefings by public affairs professionals in Canada and abroad, dealings with many of the anti-nuclear activists, and access to many sources of information, all created impressions of the debate. These were superimposed over earlier observations during twelve years in engineering journalism in Canada and earlier still by two visits to Hiroshima in 1946 during navy service.

Perhaps the vantage point was sometimes too close to the action, and the involvement too personal and emotional, to see the woods for the trees at the time. Some observations and lessons are focused more sharply with the benefit of hindsight.

Evolution in phases

The public's interests and concerns shifted significantly as the industry developed. These shifts can be related to a series of phases through which nuclear energy passed since it was first developed as a civilian technology in the 1950s.

Each development and its corresponding public attitude phase required a different type of response by the industry – a fact not always appreciated at the time and leading, on occasion, to wasted effort or phase lags between the need and industry's response.

In broad terms, four development phases can be identified. The corresponding public attitude phases for Canada, which were different than in the US and Europe, due to absence of a parallel military program here, can be expressed as follows:

Development phase:	Public attitude phase:
Transition to civilian technology	High expectations phase
Arrival of nuclear electric power	The questioning phase
Maturing of nuclear power	The backlash phase
Choice between energy options	The political phase

The high expectation phase

During this period (the 50s and early 60s) the public had little solid basis on which to form judgements about the peaceful uses of nuclear energy. However those who thought about it, with encouragement from the formation of the International Atomic Energy Agency in 1957 to "accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world", and the US Atoms for Peace program, saw nuclear scientists and engineers as technological pathfinders to a post-war utopia from their base of spectacular wartime achievements. And the public viewed them with commensurate awe and respect.

The utopia would be based on the prospect of abundant and inexpensive peaceful applications of nuclear energy. (The CNA's first booklet for the public published in the 1960s: "Radiation and Man" foresaw our railways using nuclear-powered locomotives). In April 1962 successful commissioning of the 20MW power reactor NPD at Rolphton, Ontario, launched Canada into the production of nuclear generated electricity. Because it followed quite soon after the death of the Avro Arrow, Canada's other major contribution to the cutting edge of high technology, it helped to revive public spirits and also focused public attention on nuclear energy in a new and positive way.

The "questioning" phase (late 60s and early 70s)

This phase saw the first real signs of public challenge to peaceful nuclear energy and a need for industry to respond. Opposition was fed by several streams such as Ban the Bomb activists seeking new targets to keep their groups together, budding of environmentalism, especially after the 1972 Club of Rome report "Limits to Growth", and lack of preparation by advocates of nuclear energy here and abroad to prepare for such opposition. One of the first examples of the changing climate of public acceptance in Canada was a 1972 proposal for a CANDU station near Nanaimo to help give Vancouver Island electrical self-sufficiency. Strongly supported by groups such as the local Chamber of Commerce it was equally opposed by anti-nuclear activists in the area. Then, in 1975, a throne speech in the Manitoba legislature, which foresaw installation of a CANDU within 10 years and 10 units within 25 years, also prompted public questioning of the implications. Media articles on nuclear energy at that time were often accompanied by pictures of mushroom clouds in addition to scary headlines that have been a feature of press coverage over the years.

The debate also started to broaden during this phase, especially due to Canadians' exposure to US media which frequently covered anti-nuclear topics. In 1973 a paper by the CNA Public Relations Committee noted: "Up to now information has been mainly directed to communities in which plants are located. ... Recently the situation has changed due to information from the US. This appears to have exercised a unifying influence on the Canadian protest movement." The paper proposed that efforts be made to distinguish between US and Canadian nuclear programs and engage in dialogue with the public.

A CNA response in May 1975, was the first (of three) printings of the 48-page booklet "Nuclear Power in Canada: Questions and Answers". The book contained 160 questions that had been answered by groups of specialized authorities within the CNA committee system. Widespread distribution made it a significant source of information for the public across the country. Had it been conceived earlier and published quicker it could have been even more significant. Unlike the "kitchen table" anti-nuclear material receiving publicity at the time, the emphasis was on absolute accuracy and precise wording. Difficulty in finding agreement on these by the many specialist volunteer contributors, together with the need for editions in both official languages, took their toll on production schedules – and revealed one of the problems associated with use of the printed word in the nuclear debate.

The "backlash phase" (late 70s to mid 80s)

This phase produced stronger and wider challenges to public acceptance and prompted the industry to mobilize new resources to meet the challenges.

June 1976 marked the first comprehensive study of public attitudes toward nuclear energy in Canada. Prepared by the CNA by York University's Institute for Behavioural Science and paid for by a special appeal (roughly equal to the annual budget of the CNA at that time) it revealed that only 56% of Canadians knew that nuclear energy could be used to generate electricity although 68% of those who did favoured its use. Significantly, it also revealed engineers and scientists to have the greatest credibility as sources of information and prompted the CNA to encourage participation by its members in public discussion.

The phase had been launched by India's "peaceful" nuclear explosion in 1976, an event giving added impetus and a new 'anti-exports' dimension to Canada's anti-nuclear movement which was further fed by media reports of "shady" sales agents in the other CANDU export markets.

Domestically, during this phase, the nuclear debate became a frequent media topic due to public Royal Commissions in Ontario and Saskatchewan. Also there was heightened interest in energy matters generally as a result of the oil crisis. The enquiries exposed the public to vociferous and colourful anti-nuclear arguments and antics – often helped by some accommodating media representatives. All too often, it seemed, reporters either could not separate fact from fiction due to lack of understanding of the basic facts of nuclear technology, or they would not for the sake of stimulating controversy.

The three-year Porter Commission in Ontario, which started in May 1976, and the Bayda Commission on uranium mining in Saskatchewan in 1978, together with the plan to construct New Brunswick's Point Lepreau station all helped to consolidate the anti-nuclear movement. They kept the anti-nuclear activists in the media limelight on which they thrived and gave them the high public profile on which they relied for funding. They also clearly revealed to the public for the first time that uranium mining and its associated environmental and safety issues, especially some embarrassing historical problems, are all part of the total "package" of public perceptions about nuclear energy.

The bad publicity over mishandled historical wastes... took its toll

The enquiries, to which the CNA, through its committees, had made several inputs, yielded conclusions generally very favourable to nuclear energy. However the benefits were soon offset by global fallout from the public relations disaster at Three Mile Island. In addition, domestically, the bad publicity over mishandled historical radioactive wastes at Port Hope revealed in 1976 took its toll. Some very positive news of CANDU reactors leading the world in performance followed a few years later but coverage in the media was limited – six of the top ten reactors over 500 MW worldwide were CANDUs on a lifetime performance basis in 1981. However, no sooner had the significance of this been appreciated by the public than the world's third-best performer, Pickering unit 2, suffered a burst pressure tube in August 1983 causing widespread public concern as well as a severe subsequent setback to Ontario Hydro's reactor performance figures.

On a positive note by this time the Canadian Nuclear Society was an added player in the on-going nuclear debate. It promised to provide a significant and much-needed forum for sharing the expertise and opinions of scientists and engineers who had earlier been identified as having relatively high credibility with the public. The significance of this was evident, for example, during the 1985 IPPANI hearings. For some years the World Council of Churches had shown an interest in the social issues relating to nuclear energy and the IPPANI (Interfaith Program for Public Awareness of Nuclear Issues) hearings were organized jointly by the Anglican, United, Roman Catholic, Jewish, and Ba'hai faith groups. Because of heavy involvement by the anti-nuclear group Energy Probe in the organization of the hearings, and inclusion of topics relating to nuclear weapons, the CNA declined to present a brief. However, a brief to the hearings by CNS, and by other concerned individuals in the industry, helped to offset impressions resulting from this refusal and undoubtedly contributed towards a report generally favourable to nuclear energy. Nevertheless, coverage of the report was limited by the organizers' failure to fulfill their pre-hearing distribution promises.

The "political" phase (Mid 80s onwards)

This phase saw further expansion and integration of the nuclear debate into the broader politics of energy decision-making. Unfortunately, it commenced with the Chernobyl disaster – representing the worst possible accident scenario – which graphically demonstrated global inter-relationships in the nuclear debate. In the face of the resultant strengthening of public opposition to nuclear energy and pressure from competing energy sources, the federal government began to distance itself from the nuclear industry. In terms of political support the industry now found itself being shunned by the hand that had originally nurtured it.

Pressure within the industry to stem the tide of fading support before the nuclear option was lost became intense. Ironically, however, as dust clouds from Chernobyl settled there was some silver lining in terms of public understanding. The disaster had given the media, and thereby the public, a crash course in many aspects of nuclear energy, including reactor design differences. Since media coverage itself had subsequently become an issue following TMI, coverage of Chernobyl had generally been more balanced and responsible. Also by this time, more people – especially students – had some understanding of nuclear technology and the implications of the alternatives and were therefore less easily swayed by strident polemics.

Public acceptance cannot be bought by traditional PR

The response of the CNA during this period was to direct the largest part of its effort, together with a greatly expanded budget, towards a major campaign to revive political support for the industry. It resulted in the Public Information Program (PIP) launched in 1988 and the appointment of a former federal cabinet minister as full-time CNA president. (Two earlier presidents had medical radiation physics and nuclear engineering backgrounds respectively.) A budget of several times the total budget under which the CNA had operated hitherto was achieved by a levy on member companies although Ontario Hydro, the CNA's largest member, did not contribute financially for political reasons. Subsequently PIP evolved into the CNA's Strategic Plan 1992-96 currently being introduced. It comes at a time when the public's attitude is defined as follows: supporters of nuclear energy 35%; opponents 20%; and "persuadable" 45%. It is also at a time when the public's interest in nuclear energy is lower than for many years past – so low, that it is only quoted by 2% of respondents as an issue relating to the economy and the environment.

The CNA plan, unveiled to its members in February of this year, calls for a comprehensive program of information, education and advocacy initiatives, together with a Community Outreach Program. The stated aim is to respond to the belief, not yet fully understood by the public, that "finding a way to meet future energy needs safely and sustainably is one of the most urgent political, economic, and environmental challenges facing the world community today."

Can lessons of the past guide our future?

Since "those who ignore history are doomed to repeat it" it is worth considering whether lessons from the evolution of public attitudes in Canada have relevance to future activities of CNA and CNS.

The following four facts represent a subjective view of some of the lessons.

Fact 1. We're in a "global village"

We cannot achieve or maintain good public acceptance on our own. If ever there were a 'global village' in terms of flow of information, speculation, gossip and scandal it is the one in which nuclear energy lives.

Public acceptance anywhere can be damaged almost instantly by a happening on the other side of the globe. News of reactor malfunction, safeguards violations, radioactive waste problems, sickness of uranium miners, etc., are all subject to instantaneous world-wide news coverage. What's more they are almost inevitably subject to skilful embellishment and exploitation by a well-connected international anti-nuclear network. On the other hand good news of similar local origin is rarely of global interest – it is more likely to be general in nature, such as the Club of Rome's recent endorsement of nuclear energy.

Fact 2. Public acceptance cannot be "bought"

Public acceptance for nuclear energy in Canada cannot be "bought" by traditional PR image-making techniques. In the long run – which is what really counts – it can only be "earned". The "global village" factor, together with traditional wariness – and sometimes bias – in the media, and a cunning opposition always in search of public donations through exposure, means nuclear energy is somewhat inhospitable to image-makers and spin-doctors. Fortunately the major media outlets are becoming more resistant to attempts at manipulation by the industry's detractors. However, the axiom: "the more you do, the more you need to do" can be especially applicable in nuclear PR and can easily lead to a bottomless pit of expenditures on image-making that might be better applied in other less extravagant areas.

Adding to the challenge is the way the debate ebbs and flows globally, nationally and regionally. It changes direction too – especially because anti-nuclear activists are skilful at setting its agenda. Appropriate and timely responses based on flexibility and speed of action are not easily achieved in such a diverse industry as nuclear energy. Thus, the emphasis has to be on foresight for maximum effectivenesand conservation of costs.

Fact 3: Ideal individual participants are hard to find

The learning curve for effective participation across the full spectrum of the nuclear debate is probably longer than for any other field. The fuel cycle, from uranium exploration to management of reactor wastes, involves a very wide variety of engineering and scientific disciplines. Participation requires knowledge of all energy options and spans a range of issues in economics, politics and legislation at all levels of government. The debate also covers international relations as well as more esoteric topics such as risk, epidemiology and ethical analysis. Spin-off applications such as the use of radio-isotopes for medicine, food preservation, and in industry are also put to work within the overall nuclear debate.

Even at the level of knowledge required for general public discussion few spokespersons become sufficiently familiar with both the range of subjects and the skills and psychology of effective participation in less than a decade (though this has rarely been a deterrent to participation by the industry's opponents!). In general, experienced professionals within the industry who are prepared to study the debate beyond their own specialization and able to achieve good presentation techniques will be the most effective. This is a profile that typifies many members of the Canadian Nuclear Society.

Fact 4. Corporate body language says more than words

Pronouncements of the nuclear industry are only effective when "corporate body language" revealed by the industry is in keeping with them. It is often the manner rather than the words with which genuine public concerns are handled that creates the lasting impression. Although television images can readily distort the character of people, plants, and scenes through goading, camera angles and editing, such instances, once endemic to nuclear energy, are diminishing. The public seeks a "human face" and the industry benefits when the "face" shows genuine interest and respect for their concerns.

Body language is also in evidence at gatherings of the industry, such as conferences, with their opportunities for interface with the media and the public and where impressions of opulence, wastefulness, bad planning, or even undue levity can be damaging. Pronouncements endorsed by the full breadth of industry interests are especially significant though sometimes difficult to obtain in view of the diversity of interests within the full fuel cycle. Depth can be important too. For example, various unions now participate in the affairs of the CNA. Because success in the global economy increasingly depends on three-way partnerships among management, labour and governments, the nuclear industry is well placed to be a role model in this area thereby strengthening its credibility and public support.

Fact 5. Continuing good news may require changing priorities

No matter how well the industry mobilizes communications skills for "generating a better understanding" it needs, above all, good news with which to work. Public acceptance and the political support which follows it are ultimately based on industry performance in economic, environment and safety terms. It follows that discussions about the industry's image that have preoccupied CNA and others for so long will need to yield to other ways of ensuring the on-going basis for the image remains sound.

Such topics might include promoting, and helping to develop, careers in nuclear science and engineering to offset the anticipated shortfall within ten years; coordinated industry-wide support for international marketing efforts for nuclear products and services; stepped-up involvement in the development of codes and standards that help ensure performance and protection throughout the entire fuel cycle, and so on.

For best results some of the activities will need to be undertaken by CNA in conjunction with CNS or, in a few cases, ceded to CNS entirely.

A concluding look into a crystal ball – with hope

Barring any catastrophic developments it seems likely that swings of the pendulum of public acceptance and interest will diminish as nuclear energy continues to mature, and the world becomes more dependent on it. The emphasis will likely move away from the delivery of the nuclear messages to the substance of the messages and the spotlight will fall again upon the scientists, engineers and other specialists. It is to be hoped that they will reflect the qualities of those visionaries who laid the foundation of a superb industry in this country nearly 50 years ago.

It is also to be hoped that such people and their work are covered fairly and accurately by the media wherever the nuclear discussion occurs and that public opinion accords them the respect and appreciation they deserve!

Safety and Excellence: The Regulator's Perspective

by Réné J.A. Lévesque and John G. Waddington
(Atomic Energy Control Board)

Ed. Note: *The following is an edited (for space) version of a paper given by Dr. Réné Lévesque, president of the Atomic Energy Control Board, to the 8th Pacific Basin Nuclear Conference in Taiwan, in April. It presents an intriguing insight into the developing philosophy of Canada's nuclear regulator which, we feel, should be of interest to all involved with our nuclear program.*

Introduction

Canada's nuclear industry is a large and important element of the economy. Uranium mining generates about two billion dollars in annual sales. The nuclear electrical power generating sector has an installed capacity of 13,539 MW and in 1990 generated 41.6% of the total electricity produced in the province of Ontario. Atomic Energy of Canada Limited has developed the CANDU reactor and built up a radioisotope production capability which is second to none in the world. In Canada alone, there are about 3900 users of radioisotopes. The three utilities operating nuclear power plants are competent and well respected in the electricity generating industry.

The regulatory agency in Canada is the Atomic Energy Control Board. Created in 1946, it is, we believe, the oldest independent nuclear regulatory agency in the world.

To maintain a continuing high level of operation at a very low level of risk requires excellence not only in engineering but also in organization. By the second half of the 1980's, it was becoming clear to us at AECB and to others in the industry that Canada was no longer achieving that level of excellence in a number of key sections of the nuclear industry. I would like to share with you some of the indications from which we drew this conclusion, what we and the nuclear industry are doing about it to ensure that operation in the future meets those high expectations, and some of the results that we can see so far.

Industrial Radiography

The AECB's mission is to ensure that the use of nuclear energy in Canada does not pose undue risk to health, safety, security and the environment. Its responsibility covers the whole of the fuel cycle, from the mines to the waste. 'Nuclear energy' includes, among other things, 3900 radioisotope licensees engaged in, for example, nuclear medicine, research, and industrial gamma radiography.

Organizational deficiencies were showing very clearly in part of this industry. For example, a review of the inspection results in 1989 showed that there had been a steady increase in inspections showing 'unacceptable' performance by licensees. While some of this increase was due to an earlier initiative to perform more thorough inspections, it was still apparent that over 35% of radioisotope licences were not operating in an adequately safe manner. The worst offenders were identified as industrial radiographers.

This situation developed despite the fact that specific regulations governing industrial radiography were enacted in 1983 by the AECB. The regulations impose responsibility for radiation safety on the licensee and the operator of the radiography device. They also require that operators of radiography devices pass an AECB-administered examination in radiation safety. Nevertheless, by 1989, over 40% of inspections of radiography operations showed significant problems.

The worst offenders were . . . industrial radiographers

We also analyzed doses received by radioisotope users that were in excess of the regulatory dose limits and, again, most of the people being overexposed were radiographers.

The traditional principle that licensees are responsible for ensuring that their employees are properly trained – as the 1983 regulations envisaged – clearly was not working. We have started a number of initiatives to try to correct the situation. We have published a comprehensive training manual to prepare people for the examination, administered by the AECB, that must be passed to become a Qualified Operator in gamma radiography. Since the training manual has been available, the percentage of successful candidates has increased from 50% in 1986 to 65% in 1990/91.

We have now started to prosecute not only licensees found in serious violation but also individual operators of radiography devices; and we are reviewing our radiation safety examination and intend to revise current regulations.

We have dedicated more staff time to assess applications for new licences and renewals, and have increased inspection frequency of radiography operations and the thoroughness of inspections.

We are also participating in a federal government initiative which will enable inspectors to impose fines on licensees when they observe minor violations. It is predicted that this system will increase compliance and reduce the amount of inspector time taken up by prosecutions.

It remains to be seen whether the number of overexposures and the number of 'unacceptable' inspections will be reduced as a result of these initiatives. What is clear is that the industrial gamma radiography industry was not ensuring its employees had a sufficient level of training and knowledge to properly protect themselves. The licensees had not been addressing a key organizational requirement.

It was also clear that the AECB was not meeting its mission. A much closer monitoring of licensee performance statistics has, however, given the staff of the AECB much better means of measuring the success of AECB activities.

Reactors

From 1971, when the first unit of Pickering A went critical, to the mid 1980's, the CANDU reactor had a world-wide reputation for high availability of electrical power and safe operation. By the late 1980's, a number of performance reviews by the utilities, by us, and by others, suggested that all was not well. For example, an OSART review of one station, completed in 1987, recommended 89 corrective actions. A peer review conducted by the utility, completed in 1988, identified 115 corrective actions, and a follow-up peer review in 1990 identified 232 corrective actions.

More telling was the utility's conclusion that 75% of the findings reported in the 1990 review were similar to those found in 1988. A station study of significant event reports (SERs) also indicated that a large number of events were resulting from incorrect work practices (Fig. 1). Implementation of a program to improve compliance with procedures was severely hampered by the large number of procedures that were poor or out-of-date, and hence were in the process of being revised (Fig. 2). A significant number of events involved a violation of stations' operating policies and procedures (Fig. 3).

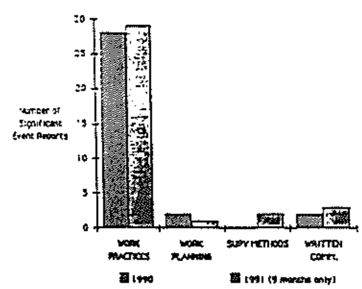


Figure 1: Procedural Compliance: consequential human error cause

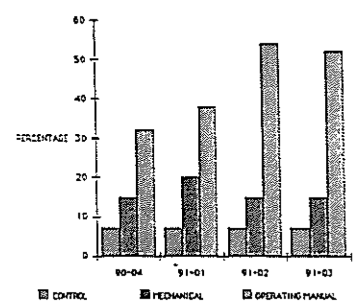


Figure 2: Procedures in Revision

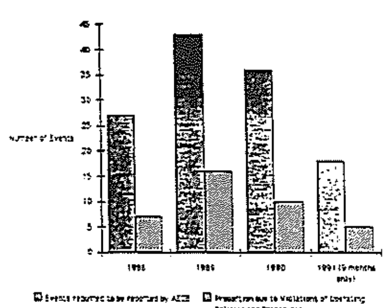


Figure 3: Reportable Events (for an 8-unit station)

The AECB also has a number of measures of performance that it has been using over the last few years. These measures cannot be used on their own; they are used in conjunction with other indicators such as direct observations by site inspectors and audit results. They can, however, be used to illustrate specific weaknesses.... One measure of performance is the degree to which station staff are trained. In one large multi-unit station, the backlog of mechanical maintenance training had reached 6000 trainee weeks in 1990. Although a significant portion of this was due to the need to train the large number of new maintenance staff hired to deal with the maintenance backlog, a large backlog had existed for some time.

With hindsight, we at the AECB should have recognized much earlier the significance of these signs. The AECB had not identified good performance measures, was not watchful enough, and needed to take corrective action. We, too, had not achieved the necessary level of excellence in regulation.

We, too, had not achieved the necessary level of excellence

The largest utility recognized something needed to be done, and reacted very positively. In 1990, it introduced a major initiative to retrieve its level of excellence: the Quality Improvement Program (QIP), covering all facets of the operation of the utility. It is too early yet to see the full effects of this ambitious program, but some trends are already emerging. The degree of maintenance re-work, for example, is dropping (Fig. 4); the backlog in mechanical training has dropped in 1991 by 1300 trainee weeks compared with 1900. The utility's peer audit in 1991 notes that "significant improvement" has occurred; compliance with Operating Policies and Procedures is improving following refresher training; and a significant increase in staff is underway to improve the level of technical support and maintenance. The QIP program was initiated by the utility's most senior management, after extensive consultation throughout the plant, including plant staff and union representatives. As a result, the program has a wide measure of support throughout the utility.

These performance measures and the utility's response are all in matters of organization that have had a significant effect on engineering and safety. I would like to bring your attention to one performance measure which is not usually used as a measure of reactor safety; the number of grievances

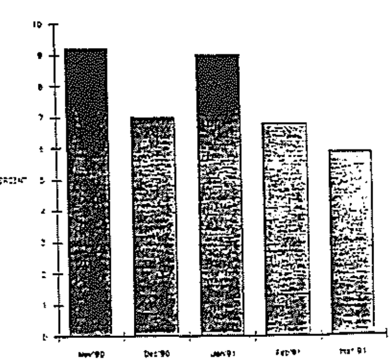


Figure 4: Maintenance Rework

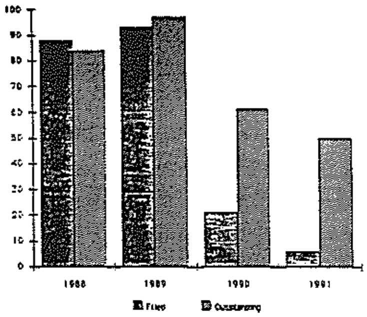


Figure 5: Grievances filed – 1991 (end of April inclusive)

filed at a particular station (Fig. 5). We interpret this as a significant improvement in the morale and motivation of station staff, which is absolutely essential to safe operation. This, we believe, is evidence of the importance of achieving excellence in the way in which a utility's organization works.

The AECB also reacted. We shortened the licence period for the stations most affected from two years to one year, and requested the utility to present its QIP program for review. We also significantly increased the level of activity in a number of key areas. Some of these areas are: on-site inspection and compliance; monitoring; review of training programs; review of system reliability and significance of human factors; improved documentation of licensing requirements; and more emphasis on configuration control and maintenance. I would like to address two issues, the inspection program and human factors, in more detail.

Inspection Program

The AECB's compliance inspection program has been significantly strengthened and made more systematic and complete compared with the level that existed in the early 1980's. The basic objective of the inspection program is to ensure that an operating utility complies with the terms of licences and applicable legislation. But the program's underlying principles go further, in that they are intended to ensure the highest practicable standards of safe operation, by promoting:

Safety: of operating personnel and the public

Quality: of reactor operations

Visibility: of regulatory staff

There are nine formal elements in the program. Each of the inspection elements may be carried out with or without prior notice to the utility, at the discretion of the inspectors, and depending on the type of inspection activity. Although a target frequency is established for each type of inspection, the actual frequency can be varied to respond to actual conditions at a site, as observed by AECB staff who are permanently stationed at each reactor site. A summary of the program elements is given in Table 1.

Table 1

TARGET FREQUENCY	INSPECTION TYPE	DESCRIPTION
Area Inspections (Rounds)	A relatively frequent area by area inspection of the plant, checking for safety hazards, condition of equipment, housekeeping, etc.	Each area inspected 6 – 12 times per year
System Inspections	A detailed inspection of each of the plant's individual systems, including its current status, maintenance and operating history, operating instructions, and events involving the system	Each system inspected at least once per year
Operating Practices Assessments	A detailed assessment carried out for an operator intensive plant condition, such as reactor start-up	As needed
Quality Assurance Audits	An assessment of the effectiveness of one or more components of the licensees quality assurance programs	One per year
Physical Security Assessment	An examination of security arrangements at the plant	One per year
Health Physics Appraisal	An assessment of one or more components of the licensee health physics/radiation protection programs	One per year
Pressure Boundary Integrity Assessment	Monitoring to confirm that all repairs, maintenance or changes to safety significant systems containing fluids under pressure are carried out to applicable codes and standards	Continuous
Emergency Preparedness Assessment	Monitoring to assess the effectiveness of licensee readiness to respond to an emergency at the plant, including assessment of drills and exercises	One per year, plus continuous monitoring
Human Performance Monitoring	Monitoring to ensure that the factors affecting human performance at the utility are properly recognised and adequately dealt with	

The last inspection element, human performance monitoring, has been included since it is clear that human factors are fundamental to safe operation. However, the content of this type of inspection still needs to be defined, and the AECB has commissioned research in this area.

The inspection program depends for its success on a particular feature of the Canadian regulatory process. At each reactor site, the AECB has established a permanently resident Project Office. Each Project Office is staffed by 3-8 Project Officers, who are responsible for the coordination of all regulatory and licensing processes for the site. Expertise for specific topic reviews and assessments is provided by specialist divisions, resident at the AECB's Ottawa headquarters. This pattern of regulation leads to a project team with extensive knowledge of the plant, its design and its safety case, and the inspection program has been designed to capitalize on this feature.

The major difficulties experienced to date in implementing this inspection program are associated with difficulties in resourcing such a wide ranging program. Additional staff recruited by the AECB in the last two years are helping to speed program implementation. Another potential difficulty, that of ensuring consistency in inspection standards between sites, is being addressed by the introduction of a 'flying squad', which will conduct inspections at each site, and by a process of exchange inspections between reactor sites to orient and train newer Project Officers.

Findings to date show that although the AECB reactor inspection program should be further improved, it is an effective means of assessing licensee operations. As expected, the findings vary widely. Poor housekeeping, failure to adequately post radiation hazards and poor maintenance standards were clear evidence of organizational malaise. Other findings have shown weaknesses in "design for operation". At one site, the system pressure of the moderator cover gas system, which has an important safety function, was not being controlled within required limits, because of inadequacies in instrumentation. In another instance, AECB staff concluded that it was not possible for operators to adequately monitor "condition guarantees" ensuring reactor shutdown, because the design made it very difficult to verify and guarantee valve positions.

Human Factors

Most of the measures of performance that have been used - significant event reports, amount of re-work needed in maintenance, poor procedures, number of outstanding temporary operating instructions - have human factors as a primary root cause. 'Human factors' in this context, is clearly not limited to the human - machine interface, (e.g. the control room) or the human - paper interface (e.g. procedures). It is the organization and management of the plant that should be examined to find the root cause of poor performance in these areas. Questions need to be asked by the utility as well as the AECB such as:

- Has the very complex task of operating and maintaining a plant been broken down into elements that make sense?
- Is the organizational structure clearly defined, and are levels of authority and accountability clearly understood by staff?
- Does the team have all the skills needed to carry out a task? Is the need to work as a team embraced by all?
- Does the responsibility to achieve high quality, 'right-first-time' tasks rest with the team and its direct supervision, or has the responsibility been diluted by an incorrect balance between those doing the job and those verifying it?
- What is, for example, the role of the supervisor versus the quality control group?
- Are plant modifications of a temporary or permanent nature carefully controlled?
- Is maintenance conducted in a disciplined and formal way to ensure it is performed expeditiously?

These factors are identical to those found by the IAEA in its study of Good Practices for Improved Nuclear Power Plant Performance.[1] The AECB believes that to achieve the right answer to all these questions, a knowledge of human factors as a specialist discipline is essential in carrying out the design, construction, equipping, operation, testing, maintenance and management of a nuclear facility. Effective application of that knowledge can only be achieved if it is integrated as part of the licensee's normal method of operation at all stages.

Safety is [not] served by . . . "rule-based" behaviour

Although all human behaviour at work can be seen as being subject to procedures, we do not believe that safety is served by an attitude that assumes a dominance of 'rule-based' behaviour. A credible human factors approach assumes that personnel use procedures judiciously when they perceive a need for them; they perform their job using their trade or professional knowledge, together with experience gained on and off the job.

People operate with a knowledge of the past, present, and an expectation of the future in a continuous manner. They anticipate the results of their own and others' actions, and model the future status of the plant and of themselves within it.[2] Most procedures, on the other hand, work in the present only. To ask people to act according to procedures as their primary method forces them to behave in a manner that is contrary to their natural behaviour at work, and is their least effective and reliable mode of operation. This can cause inefficiency and, unless it is recognised, the procedures will continue to be criticized by those who have to use them as being out-of-date or unacceptable.

Much of the effort in the nuclear industry to incorporate human factors has looked at the human/machine interface. Human performance criteria do apply at the level of the individual tasks. They also apply both to all the activities that precede the job, and to the managerial and organizational background that determines the constraints and limits within which the job is performed, such as resource allocation and utilization, and responsibility and authority relationships. All of these decisions form an environment within which personnel in the plant have to do their work. To the human factors specialist, the management team is not apart from them and controlling the process, but is an integral part of the process. The functioning of management must be analyzed and adjusted along with other parts of the system to achieve overall safety goals.

The AECB is developing a regulatory policy statement to tie human factors requirements into the formal licensing process, and to give licensees a clear statement of what evidence must be provided to show that human factors knowledge and criteria have been used.

Conclusions

The AECB and the Canadian nuclear industry had believed we were doing an excellent job. We have now realized that there were significant weaknesses in the industry which we, the AECB, were too slow to recognize and to have corrected. We have now taken, and the industry has taken, significant steps to correct these weaknesses. There are some overall conclusions from our experience which may be of value to others. None of them are new – but we found we needed to restate them.

1. To achieve the very high level of safety demanded by the public of the nuclear industry, excellence must be achieved and maintained in all elements of the business – particularly in the organization and management of the design process, and of the operation of nuclear power plants.
2. Enough staff of the right calibre and training is a prerequisite. The AECB's slowness in recognizing the signs and taking steps to ensure the industry rectified them was, firstly, due to lack of staff. The Federal Government of Canada has approved a 40% increase in the AECB's resources; the largest utility has increased its staff, particularly in the maintenance area, by 1100.
3. Good indicators of performance that can provide a continuous measure are essential (though not sufficient on their own) to discern what is happening. They are also difficult to find. We have a number which we have used; we are still looking for more.
4. The organizational complexity of designing, building and running a nuclear power plant requires that a knowledge of human factors is needed to assist management define the structure of an enterprise, and its distribution of responsibilities, training, etc., if human error (at all levels) is not to result in significant frequency of plant failures.

Over the years, the Canadian nuclear industry has put much effort into engineering excellence. It is now clear that as much effort must be put into organizational excellence to achieve a high level of safe operation. This represents a very significant challenge to the licensees and a new type of challenge for the regulator.

Notes

1. Good Practices for Improved Power Plant Performance, IAEA TECDOC 498, 1989.
2. Sheridan, T.B., "Understanding human error and aiding human diagnostic behaviour in nuclear plants", J. Rasmussen and W.B. Rouse (eds.), *Human Detection and Diagnosis of System Failures*, Plenum Press (New York), 198, pp. 19-35.

1992 CNS Simulation Symposium

Sponsored by the Nuclear Science and Engineering Division of the Canadian Nuclear Society and hosted by the Royal Military College of Canada, the 17th Annual CNS Symposium on Simulation of Reactor Dynamics and Plant Control will be held on **August 17 and 18, 1992** at the Royal Military College of Canada, Kingston, Ontario, Canada.

The scope of the Symposium covers all aspects of nuclear modelling and simulation, and usually includes sessions on systems simulation, thermalhydraulics, reactor physics, and related aspects of R&D and safety analysis.

For further information, call Dr. Hugues W. Bonin at (613) 541-6613 or (613) 541-6271, or FAX (613) 542-9489.

Symposium de simulation SNC 1992

Sous la commandite de la Division des Sciences et du Génie Nucléaires de la Société Nucléaire Canadienne et du Royal Military College of Canada, le 17ème Symposium Annuel de la SNC sur la Simulation de la Dynamique des Réacteurs et du Contrôle des Centrales aura lieu les **17 et 18 août 1992** au Royal Military College of Canada, Kingston, Ontario, Canada.

Le Symposium couvre tous les aspects de la modélisation nucléaire et de la simulation, et inclut d'habitude des sessions sur la simulation des systèmes, la thermohydraulique, la physique des réacteurs, l'analyse en matière de sûreté et sur d'autres aspects pertinents de la Recherche et du Développement.

Pour de plus amples informations, veuillez bien téléphoner au Dr Hugues W. Bonin aux numéros de téléphone suivants : (613) 541-6613 ou (613) 541-6271 ; Télecopie (613) 542-9489.

Restoring Performance at Bruce 'A'

by Ken Talbot

Ed. Note: *Following his appointment as Station Manager of Ontario Hydro's Bruce NGS 'A', Ken Talbot (a former CNS president) has given a few presentations on the plans to bring the operation of that station back to its previous high level, including one to the Chalk River branch of the CNS in February. The following is based on his notes for that talk.*

Introduction

Bruce Nuclear Generating Station "A" (Bruce NGS "A") consists of four CANDU nuclear generating units which began commercial service from 1977 to 1979. Each of the nuclear reactors is rated to produce 904 MW (electrical equivalent) of output, supplying both the Ontario Hydro electrical system, and bulk steam to the Bruce Nuclear Power Development and the nearby Bruce Energy Centre.

Bruce NGS "A", together with its companion station Bruce NGS "B", the Bruce Heavy Water Plant, and the associated site facilities make up the Bruce Nuclear Power Development (BNPD) on the shore of Lake Huron, about 120 km north west of Toronto. The BNPD is the largest single site nuclear power development in the world.

The performance of Bruce NGS "A" peaked in 1984 with a station capacity factor (average of the 4 reactor units) of 94.0%, and a best unit performance of 98.2% capacity factor. During this period, a world record for continuous operation was set by Bruce NGS "A" unit 3 at 495 days of continuous operation. This record still stands as the longest continuous run of any commercial reactor unit in the world.

From 1984 to 1990 station performance deteriorated continuously. In hindsight, it appears that during the years of excellent performance, budgetary restraint eroded the capability of performing preventative maintenance and skilled staff were redeployed to newer stations being commissioned. An adversarial form of labour management relations also developed.

Although initial performance was excellent, the station was run at peak output without sufficient maintenance due to restraint and possibly complacency. Eventually, equipment began to fail, work backlogs built up, and performance deteriorated.

This paper describes the strategies and programs being put in place to rebuild the capability to solve "technical" and "people" type problems in order to restore Bruce NGS "A" to excellence.

Problem Recognition

Following the Three Mile Island 2 Nuclear Power Plant accident in 1979, the Institute of Nuclear Power Operators (INPO) was established in the United States to ensure that lessons learned at one nuclear power plant could be effectively communicated to other nuclear power plants. A key feature of the INPO program became periodic reviews of the entire spectrum of station performance (safety, reliability, maintenance, operation, technical support, training, organization, administration, and so on) by a committee of "Peers", to judge performance objectively against a set of performance objectives and criteria. Ontario Hydro has developed its own "Peer Evaluation" system as a tool to assess station performance.

An initial INPO assessment was conducted at Bruce "A" in 1986, followed by Ontario Hydro "Peer Evaluations" in 1987, 1989, and 1991. These evaluations identified a need to improve operational performance in many areas, and a need to augment station personnel resource levels to enable a return to good operation and a reduction in backlogged work.

At the same time, the Atomic Energy Control Board (AECB) identified, in its annual review of Bruce NGS "A" performance, that there were significant concerns in the conduct of Operations and Maintenance at Bruce NGS "A". The station was granted an operating licence for only one year instead of the normal two years as a means of maintaining regulatory pressure on Ontario Hydro to improve the station performance.

Technical Problems

The technical issues facing Bruce NGS "A" can be divided into four main areas:

- pressure tube issues
- steam generator performance
- equipment refurbishment
- system upgrades

Pressure tubes

There are 480 pressure tubes in each Bruce NGS "A" reactor. Hydrogen, either left behind as a part of the pressure tube fabrication process, or dissolved into the tubes during operation from the heat transport system (hydrogen is routinely added to the heat transport system to scavenge oxygen for corrosion control purposes) can concentrate and precipitate in the pressure tubes in either of two locations:

- at points of high material stress
- at points of contact between the hot pressure tube and the cooler surrounding calandria tube, since the hydrogen is less soluble at lower temperatures.

Concentrations of precipitated hydrides can produce cracks in a pressure tube. Two corrective programs are in place to prevent pressure tube failure from such a mechanism.

Pressure tube life can be extended by ensuring that the pressure tube is not in contact with its surrounding calandria tube, by locating the spacers which separate the tubes in an optimum manner. This Spacer Location and Repositioning (SLAR) program uses non-intrusive inspection techniques to locate the spacer, and an inductive field to move the spacer to the optimum location. Two units at Bruce NGS "A" are scheduled to have pressure tube SLAR in 1992 and 1993.

Additionally, the pressure tube hydrogen concentration is calculated by a model which adds initial hydrogen levels to in-service pickup. The model is confirmed by sampling the pressure tube material during outages. When the pressure tube hydrogen concentration reaches a predetermined limit, pressure tube replacement is required. Pressure tube replacement on the first unit at Bruce NGS "A" is scheduled to begin in 1994. Pressure tube replacement in all four units will be complete by 2006.

Steam Generator Performance

Each Bruce NGS "A" reactor unit has eight steam generators (boilers), with each boiler having over 4800 tubes about 1.25 cm in diameter. The performance of the steam generators can degrade in several ways:

- Deposition of solids can plug small passageways, and result in flow instability, which is observed as boiler level oscillation.
- Gradual deposition of impurities on the tubes reduces heat transfer and results in an increase of the temperature of the heat transport coolant. This lowers the amount of heat which can be removed from the fuel bundles before boiling occurs, thereby reducing reactor output capability.
- Chemical impurities can promote corrosion of the tubes, and lead to leakage of the heavy water primary heat transport coolant into the light water secondary feedwater side.

Due to the build-up of depositions on the tubes two units had to be derated. Over the last three years the boilers on these units were cleaned by high pressure water lancing to remove deposition of solids. The same two units are now experiencing intermittent boiler tube leakage. Future plans include chemical cleaning of the steam generator tubes and taking measures to reduce the incidence of stress corrosion initiated cracking and tube vibration.

Equipment Refurbishment

Much of Bruce "A"'s equipment has suffered from lack of preventative maintenance. Some of this equipment must now be replaced or restored to its original condition. A comprehensive equipment refurbishment program is planned to cope with this backlog of maintenance activities. This program (Rehab) is planned to take place during the first two unit's Retube outages, and during shorter outages prior to the last two units Retube outages. The intent of the Retube and Rehab outages is to restore the Bruce NGS "A" performance to an 85% capacity factor.

System Upgrades

In addition to the restoration of equipment condition some modifications have been identified as necessary to maintain a high capacity factor and to meet regulatory standards which have changed since the station was built. For this reason, during the Retube and Rehab outages, some system upgrades will be carried out. These include addition of new reactor trips, and upgrades to other safety systems to meet new standards.

Rehab Program

The Bruce NGS "A" Rehab program identified 42 individual projects which were to be considered for restoration of station performance. They were categorized as:

- 5 projects (10%) related to Employee Safety Issues
- 8 projects (21%) related to regulatory and environment issues
- 29 projects (68%) related to reliability and cost improvements.

In total, the project commitment was seen as an investment of 854 M$ for capital (new equipment) or for operating and maintenance (replacement) modifications.

The Bruce NGS "A" long term Retube and Rehab program is scheduled to continue over 13 years.

During the years of the Rehab program, the projected total unit energy cost for Bruce NGS "A" is predicted to be in the range of 25 to 40 $ per MWh. These costs demonstrate that Rehab of Bruce NGS "A" is still cost effective.

People Problems

In the same manner that plans needed to be established to deal with the technical problems facing Bruce NGS "A", plans were also needed to deal with apparent "people problems". The staff at Bruce NGS "A" number over 800, and supporting staff from site service groups, from contractors and construction, and from external service organizations bring the total number of people whose work directly affects Bruce NGS "A" to well over 1500. It was clear that any plan to restore Bruce NGS "A" to excellence would require that all of these individuals be enthusiastically committed to the job.

It was also clear that to be successful in restoring Bruce NGS "A" performance, the established pattern of adversarial conflict between union and management, and between station and support groups would have to change. The key to the change in climate is to come from a Quality Improvement Program.

Quality Improvement Program

The Quality Improvement Program is based on the principle that workers, supervisors, and managers are all involved in the management process at the station in an effort to achieve excellence. The program focuses on correcting deficiencies, and on ensuring that future operation is consistent with a set of performance guidelines and criteria. At Bruce NGS "A", a working group of managers, employees' representatives (Ontario Hydro Employees Union – OHEU), professional and administrative staff representatives (Society of Ontario Hydro Professional and Administrative Employees – Society), and support staff formed a Quality Improvement Action Committee (QIAC) to put in place a new working relationship in which everyone had a voice in determining the station direction.

One of the initial actions of the QIAC was to agree on a MISSION and a VISION for Bruce NGS "A". The following were adopted:

Mission

The Safe Generation of Electricity

Vision

Our Goal at Bruce NGS "A" is to achieve leadership in the electrical generating industry. We will accomplish this when people know that they have become our most valued resource and when our performance becomes the model for others to follow.

Managing Council

After having agreed on a station mission and vision, the QIAC was amalgamated with the station managing process and a "Managing Council" formed. This Managing Council ensures the representation of all station staff in decision making affecting the station. The composition of the Managing Council is as follows:

Station Manager
Production Manager
Technical Manager
Rehab/Retube Manager
Planning Superintendent
Quality Assurance Superintendent
Two OHEU (Union) Representatives
Professional and Administration Staff Representative
Joint Health & Safety Committee Representative
Human Resources Section Head
Comptroller

The Managing Council meets routinely on a weekly basis, and more often if required to discuss and decide on issues facing the station.

Keys to Quality Improvement

At Bruce NGS "A", it is recognized that to be successful in restoring the station to excellence, it will be necessary to carry out effective strategic planning, so that a direction common to all can be set. Because of limited resources, and the fact that success tends to breed more success, it is important to initially focus on a few areas and set realistic targets so that success can be demonstrated. Above all, it is clear that success will require the teamwork of all station staff and of support groups such as Atomic Energy of Canada Limited and Ontario Hydro designers. Good communications with the regulators are also key to our achieving success, and open communications with the Atomic Energy Control Board and other regulators such as the Ontario Ministry of Consumer and Commercial Relations (who regulate the Boiler and Pressure Vessel Act in Ontario) and the Ontario Ministry of the Environment are encouraged.

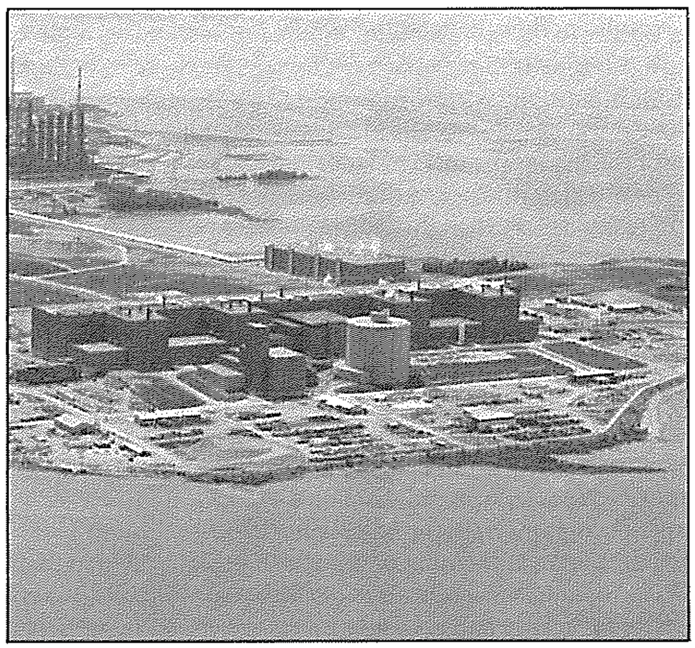
Finally, it is realized that the Quality Improvement Process requires constant monitoring and constant and continuous improvement as it grows.

Quality Improvement Results

As a result of focusing on a few key issues, the following results were achieved in the first year of operation of the Quality Improvement Program.

- the number of temporary changes to systems in existence was reduced (by over 40% for those with Technical Section responsibility)
- the overall Chemistry Performance increased significantly (indicating that more systems were maintained within specifications more of the time)
- the internal radiation dose committed to chemical technicians was reduced
- the number of pages of temporary operating instructions was reduced by over 50%
- generator hydrogen seal change completed in 4 days instead of the normal 10
- the amount of radiological waste generated was reduced

These early improvements demonstrate that by focusing, significant improvements, which decrease the complexity of operation of the station and improve overall performance, can be made by means of working in a team spirit of cooperation.



Conclusions

The restoration of Bruce NGS "A" to excellence will be dependent on the team efforts of all station personnel and on numerous personnel from outside the station. A management system has been established which allows the input of all station personnel to the decision making process for the station. Application of this Quality Improvement Process, with focus on Strategic Planning and teamwork to work on a few achievable tasks at a time, has been demonstrated as effective in making significant improvements.

Finally, the restoration of Bruce NGS "A" to excellence not only makes economic sense, it also ensures that personnel who devote their working career to providing power to the people of Ontario do so in a climate which encourages them to do their best and to achieve personal satisfaction.

CANDU Life Extension Through Large Scale Fuel Channel Replacement

Adapted from a paper presented to the 8th Pacific Basin Nuclear Conference in Taiwan, April 1992.

Brian R. Churchill
(Ontario Hydro)

Introduction

The year 1992 marks the thirtieth anniversary of CANDU reactor operation in Canada. This design of pressure tube reactor has enjoyed safe, effective and reliable performance as a major source of electricity generation not only in the Canadian provinces of Ontario, Quebec and New Brunswick, but also in India, Pakistan, Korea and Argentina. Further CANDU units are under construction in Romania and Korea.

The basic components of a CANDU core are the calandria vessel, the fuel channels and the reactivity control mechanisms. Of these, the fuel channels and the reactivity mechanisms are replaceable. The calandria vessel, a large stainless steel tank, experiences conditions of relatively low temperature and pressure, and is designed for very long life. The fuel channels, in particular the pressure tubes, are exposed to an environment that combines high flux with high temperature water at high pressures, which induces changes in the properties and dimensions of the channel components.

As a fundamental requirement CANDU fuel channels were designed to be replaced because of the difficulty in predicting the behaviour of zirconium alloys in such service over durations of up to 30 years. In fact, some phenomena, that were not fully recognized at the time of the earliest station designs, have led to unacceptable changes in the properties of the channels in several of these reactors. This has led to Large Scale Fuel Channel Replacements (LSFCR) of those reactors where economically justified.

These deficiencies have been corrected in the later designs, and fuel channels in reactors that have commenced operation over the past 12 years are expected to reach the intended 30 year life. LSFCR may then be implemented in order to extend the station life.

Reactor and Fuel Channel Design

In the CANDU reactor the heavy water moderator is contained in a large stainless steel vessel, or calandria. The calandria is a cylindrical vessel, typically 6 m long by 6 m in diameter, whose planar surfaces or end shields are joined by tube penetrations called calandria tubes. Calandria tubes of zircalloy-4 material are attached by sandwich rolled joints to the calandria end shields and form an integral part of the calandria structure. The pressure tubes, approximately 10 cm in diameter and 6 m long, pass through the core inside the calandria tubes and are separated from them by spacers (garter-springs). The concentric arrangement forms an annular gap which is filled with an insulating gas.

The pressure tubes are attached by roll expansion at each end to stainless steel end fittings. These end fittings each have a bolted seal ring connection on a side port to allow the connection of a carbon steel feeder pipe which carries the heat transport water to and from large diameter headers. These are connected to the primary coolant pumps, the steam generators and auxiliary circuits. Each end fitting has an end seal or closure plug that is accessed on power by a fuelling machine which is mounted on a movable bridge at the face of the reactor.

The major elements of a fuel channel are shown in Figure 1. There are four garter springs (only two in earlier reactors) formed from square cross-section wire. These spacers are intended to accommodate any relative motion of the two tubes and are designed to prevent contact between the pressure tube and the calandria tube. The end fittings slide on bearings and the annular space between the calandria and pressure tubes is filled with CO_2 gas, (nitrogen in early reactors) which is circulated and monitored for moisture. The annulus gap is sealed with Inconel bellows, which are welded to a shrink fitted ring mounted on the end fitting. Each fuel channel is located in the core by a centering device (positioning assembly) which attaches the end fitting to the end shield.

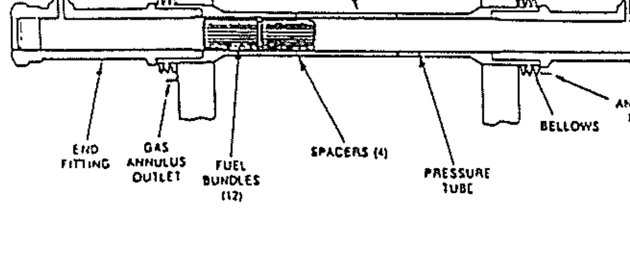


Figure 1: Simplified Cross Section of a CANDU Fuel Channel

Factors Influencing LSFCR Planning and Implementation

The first CANDU generating station, the 25 MWe Nuclear Power Demonstrator (NPD), was first taken critical in 1962 and operated successfully until it was shut down in 1987. Succeeding Ontario Hydro stations were: Douglas Point (220 MWe – started in 1966), the four Pickering A 540 MWe units (1971-3), four Bruce A 900 MWe units (1976-9), the four Unit B stations at Pickering and Bruce, and the four 935 MWe Darlington units.

At NPD, individual fuel channels were replaced on a number of occasions to obtain surveillance data for the ongoing CANDU program. Both NPD and Douglas Point were shut down for economic reasons. Although LSFCR was considered, it was not judged to be appropriate because of the small size and proto-typical nature of these stations.

Pickering A experienced several pressure tube leaks in 1974/75. These were in the Zr-2.5% Nb alloy pressure tubes used in Units 3 and 4, and were caused by delayed hydride cracking due to incorrect installation procedures. Experience was gained in the replacement of several dozen pressure tubes, and the reactors returned to service. Evaluation of the removed tubes confirmed on-reactor measurements of elongation due to irradiation. It was projected that this elongation (creep) would consume the maximum allowable end fitting bearing allowance well before the 30 year design life was achieved. The need for an LSFCR capability was thus identified to enable life extension for a total of six reactors (four at Pickering A, and Bruce Units 1 and 2).

Planning for this LSFCR capability was underway in 1983, when a sudden and unexpected rupture of a Zircalloy-2 pressure tube occurred in Pickering Unit 2. Subsequent investigation of the causes of this failure determined that garter springs were displaced and the pressure tube material was hydrided, and had suffered a loss of ductility. The contact between pressure tube and calandria tube had provided the point of initiation of the failure. Over the course of several months it was determined through inspection and sampling that a significant percentage of the fuel channels in Pickering Units 1 and 2 were in a similar condition to the channel that failed.

In March 1984, the decision was taken to proceed with LSFCR simultaneously for these two units. This decision acknowledged a recent Corporate change to extend the 30 year design life for Ontario Hydro CANDU units to 40 years.

Fuel Channel Replacement Operations

There are four distinct stages to LSFCR operations: preparation, removal, installation and recommissioning. Preparation begins with the defuelling of the entire core using the regular fuel handling system, with all fuel transferred to the storage bay. This is then followed by a decontamination of the primary circuit. The addition of chemicals to the heat transport water (CANDECON treatment) causes the release of radioactive oxides from the piping surfaces to a collection and filtering system. This reduces the radiation fields at the reactor faces to a manageable level. The moderator system is drained and many auxiliary systems placed in a"lay-up" mode generally under an inert cover gas. The primary system is then drained and vacuum dried to recover the heavy water and reduce tritium contamination levels before flushing with light water.

Removal

The removal phase begins with the removal of the fuelling machines and installation of a shielding cabinet on each fuelling machine bridge (Fig. 2); installation of services in the vault (power, air, communications); and installation of robotic equipment into the shielding cabinets to be used during the removal of the highly radioactive components.

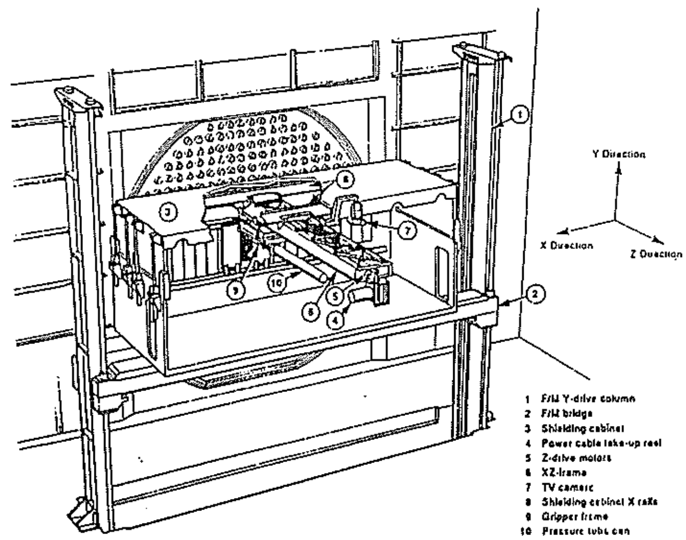


Figure 2: Shielding Cabinet Installed at the Reactor Face

The removal phase operations consist of handling both low level and highly active components in addition to dealing with high levels of loose contamination. In order to safely address these hazards a combination of manual, semi automatic and remote operations is used to minimize dose uptakes and improve efficiency in the largely repetitive tasks.

The following reactor components are removed and disposed of during this Phase (ref. Fig. 3):

- feeder grayloc capscrews, feeder grayloc seal rings
- bellows heat rings
- end fitting shield plugs
- major portion of each stop collar on reactor west face
- end fittings, pressure tubes, fuel channel spacers (garter springs).

The Removal Phase activities are organized into groups or "series". Each series is normally completed over the entire reactor face before the next series starts. Each series is normally a complete and independent part of the removal process (e.g. feeder capscrew removal, pressure tube removal, etc.). Most series are performed on both reactor faces. As much as possible, no dependency or ties exist between activities occurring simultaneously on both reactor faces.

Installation

As opposed to the removal phase, the installation process concentrates on a row of channels with all work being com-

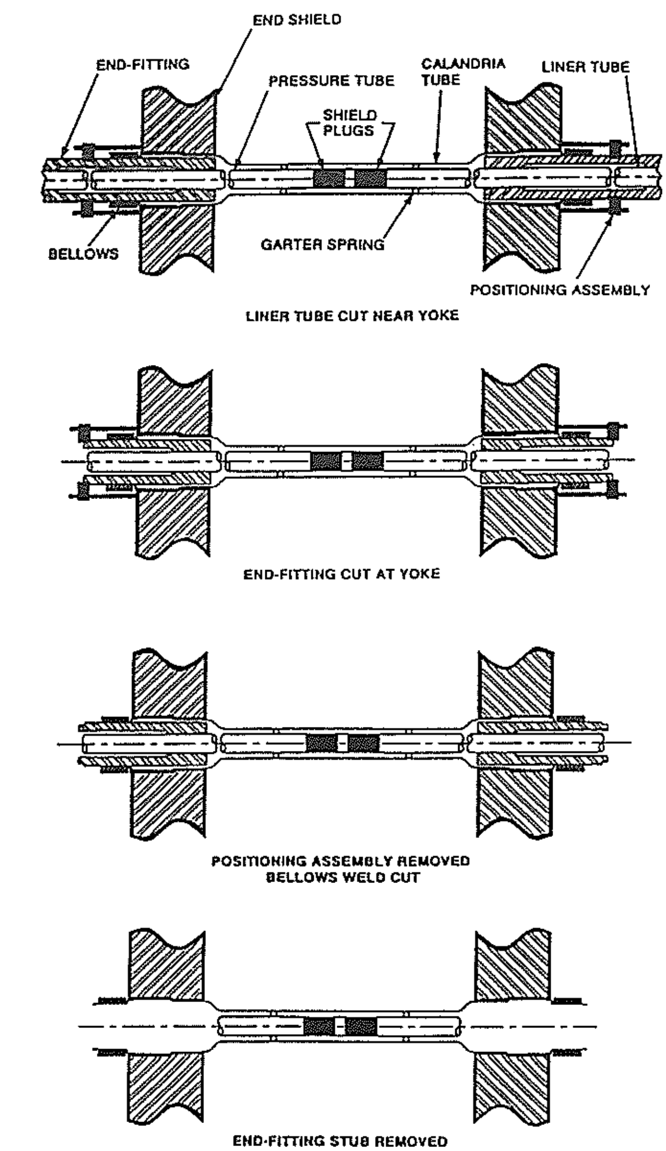


Figure 3: Sequence of Operations during Channel Removal

pleted on a specific row before progressing. This is summarized as follows:

- Install sub-assembly and clamp in position (Note a sub-assembly consists of an end fitting with a pressure tube rolled in and tested).
- Weld the bellows to the End Fitting attachment ring.
- Install and lock Positioning Assembly hardware.
- Straighten the Pressure Tube (if required).
- Install End Fitting, and roll in Pressure Tube.
- Weld bellows to End Fitting attachment ring.
- Reconnect the Grayloc feeder hubs.

Critical Success Factors for LSFCR

LSFCR is the largest and most complex rehabilitation task ever undertaken on CANDU units. Throughout every stage of the program, safety (both conventional and radiological) and quality were of paramount importance and were not to be compromised in any way. The LSFCR outage is schedule driven to a very large degree because of the high cost of the replacement energy required. Despite the schedule demands, there are major budgetary pressures to complete the work within the authorized funds. With a reactor out of service for LSFCR, every effort is made to capitalize upon the available outage time to execute other rehabilitation and major maintenance work needed to assure required lifetime performance.

To successfully achieve these many competing objectives, the following are critical factors.

Project Management

For the four LSFCR projects at the Pickering station, the project management approach has evolved from unit to unit. At the time that P1/P2 LSFCR was committed, the four unit Pickering B station was still under construction, with an existing structure for management of engineering, construction and commissioning. The LSFCR program was super-imposed on this organization, along with selected resources. Although the planning, tooling design and proving, and eventual implementation were generally executed by a dedicated group, the overall project management approach did not readily adapt from a "green-fields" project to one of a rehabilitation program within an operating station environment.

This resulted in a lack of focus on achieving the LSFCR in the shortest possible time because resources were continually diverted to deal with emergent problems with the operating units. The safety and radiation dose performance was satisfactory, and the work was accomplished on budget, but the replacement energy cost was excessive. Full documentation of the reasons for lost time enabled a much more effective project management approach to be employed for Pickering Units 3 and 4.

Integrated Retube/Rehabilitation Outage Management

Pickering Unit 3 LSFCR outage, started in 1989, witnessed the first successful application of a multi-functional team of resources dedicated solely to both the retubing and rehabilitation of a single unit. Overall project management and outage management were integrated to maximize the opportunities to upgrade many other plant systems without extending the critical path set by LSFCR.

For Bruce 1, where the extent of the rehabilitation work is far greater than was the case at Pickering, even closer integration of planning, control and scheduling of all LSFCR and concurrent work will be implemented.

The improvements in schedule reduction at Pickering have been very substantial as shown in Figure 4. It should be noted that the Bruce reactor has 20% more fuel channels than Pickering.

Resources

The key resources critical to the success of LSFCR are: people, time, tools and facilities, and radiation absorbed dose. Careful planning, attention to detail, and full utilization of lessons learned from one reactor to the next were applied for each resource.

People

Continuity of key personnel has proven to be critically important. The ability to dedicate staff to the project from start to finish was difficult to accomplish, but the results particularly for Pickering 3 prove the value of this action.

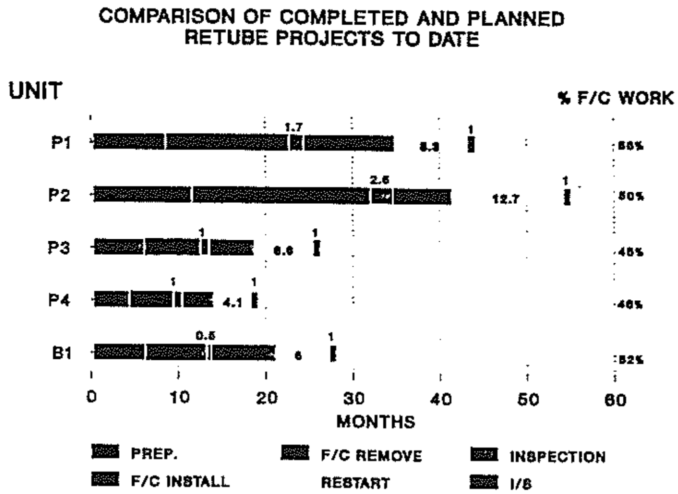


Figure 4: Duration of Retubing Activities, Actual and Predicted, for Five Reactors

The sense of ownership and teamwork was far greater than had been achievable previously. The results were a 35% reduction in cost in constant dollars, and almost a 50% reduction in schedule from P1 / P2 experience.

Time

The most effective use of every available hour each outage day for productive work is crucial. With adequate planning, suitable labour relations agreements and attention to detail (such as using split shift crews starting at different times to cover meal breaks) it has been shown that up to 22 of 24 hours can be readily utilized productively. The other two hours are used for clean-up and special purpose "hit-teams" trouble shooting specific tooling performance issues.

Planning, experience and detailed analysis of past data on instances of lost time, are the most valuable tools for managing this resource.

Facilities and Tools

A significant investment in a full-scale reactor face mock-up, and many smaller mock-ups has proven invaluable.

Intensive orientation and training of Tradespeople has increased productivity, improved safety and saved time and money. In addition, extensive tool proving and development can be done in a non-hostile environment.

The Training and Mock-up Building at Pickering has in many ways been the focal point of much of the LSFCR activity progressively from unit to unit.

A similar facility is being built at Bruce A.

Radiation Absorbed Dose

While perhaps not obvious initially, radiation dose both to each individual and in total is a key resource to be managed throughout LSFCR. In fact, most of the tool design and procedures for use were strongly dictated by the need to meet ALARA requirements. However, management of shift crews, to maximize learning curve skills for repetitive activities in a high radiation hazard environment, is essential to minimizing dose. A successful CANDECON decontamination is equally important.

Considerable progress has been made in this aspect of LSFCR including the virtual elimination of a carbon-14 hazard discovered on Pickering 1 and 2. Current technology and procedures for dosimetry, dose records and management must be 'state-of-the-art'. Pickering 3 was completed safely for a total dose that was 8% below target for the project.

Technology Advances

There has been a steady flow of successful design and process improvements over the past seven years, but no really dramatic technological 'step-changes' in LSFCR.

Bruce Unit 2, currently scheduled for retubing in 1997, is the target reactor for the first application of significant technology advances to reduce doses, outage time and cost. Development work is already underway towards meeting this target.

Summary

LSFCR has been successfully implemented for three of the Pickering A reactors to enable a minimum 40 year operating life to be achieved. Over the next few years, the fourth Pickering A Unit will be completed along with the first of the Bruce A reactors, providing the opportunity for life extension of these units.

Ontario Hydro has long range plans that call for the retubing of all Pickering B, Bruce B and Darlington units for life extensions. The economics of CANDU, including the impact of one major LSFCR outage, continue to compare favourably, with alternate sources of supply for base load generation. As operating experience with fuel channels continues to accumulate, it is possible that life extension of the current generation of CANDU reactors may be achievable without LSFCR. However, the latest CANDU-3 reactor from AECL has been specifically designed for convenient retubing more than once during an extended operating lifetime.

Acknowledgements

I would like to thank the many staff of the Retubing Projects organization of Ontario Hydro, both for their contributions to this paper, and for their accomplishments with LSFCR at Pickering. Also, a special thank you to Mr. J.O.N. Allen of Ontario Hydro and Mr. E.G. Price of Atomic Energy of Canada for LSFCR reference material compiled July 1991.

13th Annual Conference

Saint John, New Brunswick, Canada
June 7-10, 1992

Schedule of CNS Annual Meeting Scientific Sessions

June 8, Monday P.M., 14:00-17:30

CNS Session 1: **Reactor Physics**
Chairman: B. Rouben, AECL CANDU

14:00 WIMS-AECL Calculations for the Doppler Coefficient of Reactivity
by: F.C. Wong

14:30 Reactor Physics Aspects of Modelling In-Core Small Loss of Coolant Accidents
by: E.V. Carruthers, M.Z. Farooqui, A.S. Adebiyi, G. Gaboury, H.S. Smith and M.B. Gold

15:00 ORIGEN-S Cross Section Libraries for CANDU Reactor Used-fuel Characterization
by: I.C. Gauld

15:30 An Automated Procedure for Excluding Readings of Failed Detectors in Flux Mapping
by: B. Rouben, H.W. Dassen and K. Ossia

16:00 The Use of Depleted Uranium for the Reduction of Void Reactivity in CANDU Reactors
by: A.R. Dastur, P.S.W. Chan and D. Bowslaugh

16:30 Techniques in Calculating Moderator System Heat Load at Full Power and Following Reactor Transients for CANDU 6 Reactors
by: K. Aydogdu

17:00 Description of Physics Data for CATHENA Safety Analysis of the MAPLE-X10 Reactor
by: P.A. Carlson, R.J. Ellis, H. McIlwain and E.F. Talbot

17:30 Close of Session

CNS Session 2: **New Concepts and Technology**
Chairman: F. Stern, SLI

14:00 The Concept of a Passive Water-Cooled Tube Reactor Without Emergency Core Cooling System
by: Soon Heung Chang and Won-Pil Baek

14:30 Design Concepts for Passive Heat Rejection in CANDU Reactors
by: J.H. Beaton, N.J. Spinks and R.F. Dam

15:00 Uprating of CANDU Reactors – A Feasibility Study
by: S.S. Dua, T. Lee, J. Mistry and C. Lee

15:30 Modern Turbine-Generators for Standardized Nuclear Power Plant
by: J.A. Hesketh

16:00 Fast Acting Liquid Shutdown System
by: U.C. Muktibodh, B.B. Narang, A.K. Asundi, S. Ghosh and A. Natarajan

16:30 Design of the Internal Geometry of an Advanced Containment for Mitigating Deflagration Overpressures
by: M. Carcassi and F. Fineschi

17:00 D_2O Production by Laser-Induced Selective Multiphoton Decomposition (MPD)
by: R.D. McAlpine, M. Ivanco and G.A. McRae

17:30 Close of Session

CNS Session 3: **Fuel Behaviour**
Chairman: H.E. Sills, IDEA Reseach

14:00 Fission Product Release from HEU Uranium—Aluminium Alloy fuel in SLOWPOKE-2 Reactors
by: A.M.C. Harnden, B.J. Lewis and L.G.I. Bennett

14:30 Assessment of Fuel Defects in Darlington NGS
by: P.J. Reid, F.C. Iglesias, M.J. Dymarski and S.T. Lim

15:00 Transport Theory Evaluation of the Release of Short-Lived Fission Products from Fuel Gains
by: H.E. Sills and Y. Liu

15:30 Sheath Protection Mechanism Afforded by CANLUB
by: P.K. Chan, I. Aitchison and G.M. MacGillivray

16:00 Extended Burnup Fuel: A Comparison between Measured and Predicted Fission Gas Release Using ELESIM
by: W.R. Richmond and J.M. Bunge

16:30 Particle Size Distribution of U_3O_8 Produced by Oxidation of Fuel in Air at 300-900° C
by: Z. Liu, C.E.L. Hunt, D.S. Cox and R.D. Barrand

17:00 Dissolution of UO_2 Fuel by Molten Zircaloy-4
by: P.J. Hayward, I.M. George and M.C. Arneson

17:30 Close of Session

CNS Session 4: **Reactor Design**
Chairman: P. Lafreniere, Hydro Quebec

14:00 Large Deflection and Elastic-Plastic Piping Stress Analysis of Feeder and Feeder Supports used in a CANDU Reactor
by: K. Chaudhry, S.A. Usmani, T. Lee and C.C. Yao

14:30 Seismic Optimization Approach for CANDU Modules
by: R.A. Ricciuti, A. Alizadeh and H. Jaikaran

15:00 Slarette Mark 2 Delivery System
by: D.J. Burnett

15:30 Control of CANDU 3 Fuel Handling Operations Using a Dedicated Distributed Control System
by: D. Arapakota, J.A. Yip and R. Anderson

16:00 A Systems View of CANDU Reactor Retubing
by: M. Cobanoglu

16:30 CANDU-3 Systematic Plant Review – A New Approach
by: R.K. Jaitly and P.J. Allen

17:00 Derivation of Component Failure Data and Trend Analysis at Point Lepreau Generating Station
by: D. Mullin and T. Shaubel

17:30 Close of Session

June 9, Tuesday A.M., 08:00-12:00

08:00 *CNS Annual General Meeting*

CNS Session 5: **Safety Analysis 1**
Chairman: D. J. Richards, AECL-WL

09:00 *Pressure Oscillations in Darlington NGS Primary Heat Transport System Due to Tripping of One Main Circulating Pump*
by: D.G. Meranda, A. Despotovic, V. Hera, J. Rubin and C. Schraeder

09:30 *Computer Code Verifications for PHT Purification System*
by: F. Su and H. Goulding

10:00 *Integrating CATHENA with CANDU Plant Controllers*
by: D.J. Richards and R. Girard

10:30 *Simulation of the Combustion Chamber of a* H_2-O_2 Thermal Recombiner
by: F. Fineschi, M. Bazzichi and G. Gardano

11:00 Thermalhydraulic Transient Analyses of the SGECS Initial Injection Period
by: B. Phillips and J.Y. Stambolich

11:30 Thermalhydraulic and Thermal Analysis of the CANDU 3 Reactor Endshield for a Loss of Flow Event
by: T.K. De and W.M. Collins

12:00 Close of Session

CNS Session 6: **Safety Analysis 2**
Chairman: J. Almon, Ontario Hydro

09:00 Assessment of Shutdown System Trip Parameter Effectiveness of CANDU Reactors Following In-Core Loss of Coolant Accidents
by: A.F. Oliva and L.J. Watt

09:30 Bruce NGS: Assessment of Calandria Tube Integrity Following a Sudden Pressure Tube Failure
by: P.S. Kundurpi, A.P. Muzumdar and F.B.P. Tran

10:00 New Flux Detectors for CANDU 6 Reactors
by: J.M. Cuttler and N. Medak

10:30 Simulation of a CANDU Reactor Using a Real-Time Advanced Reactor Core Model
by: Hoang Tran-Duc

11:00 Multi-Frequency Eddy Current Test Applied for Steam Generators of Daya Bay Unit 1
by: Cheng Huiping, Li Yiquing and Yang Baochu

11:30 CATHENA Validation Against MAPLE Subcooled Boiling Data
by: T.V. Tran, S.Y. Shim, J.E. Kowalski and M. Salcudean

12:00 Close of Session

CNS Session 7: **Fuel Channel Behaviour**
Chairman: H. Huynh, Hydro Quebec

09:00 Pre-test Simulations of the CHAN 28-element High-Temperature Thermal-Chemical Experiment CS28-1 Using CATHENA and CHAN-II-WL
by: Q.M. Lei, D.B. Sanderson and H.E. Rosinger

09:30 Simulations of Molten Zircaloy/Pressure Tube Contact Experiments Using Computer Codes WALLZ5 and MINI-SMARTT-II
by: M.H. Choi, M. Bayoumi and P.S. Kundurpi

10:00 Experimental and Theoretical Investigation of Pressure Tube Circumferential Temperature Gradients During Slow Coolant Boil-Off
by: Q.M. Lei, M.L. Swanson and H.E. Rosinger

10:30 Further Simulation of the Pressure Tube Circumferential Temperature Distribution Experiments (Make-up Water Experiments)
by: M. Bayoumi, W.C. Muir and P.S. Kundurpi

11:00 Theoretical Prediction of the Garter Spring Positions along the Channels of CANDU Reactors
by: C.H. Borzi

11:30 Bearing-Pad/Pressure-Tube Rupture Experiments
by: R.G. Moyer, D.B. Sanderson, R.W. Tiede and H.E. Rosinger

12:00 Close of Session

CNS Session 8: **Equipment and Design Qualification**
Chairman: A. Baudouin, Hydro Quebec

09:00 Concrete Containment Leak Tightness Aging Time History and Preventive Methods
by: C. Seni and N. Garceau

09:30 Ontario Hydro's Program for Environmental Qualification of In-Service Plants
by: J.A. Blasko and R.P. Lindsay

10:00 Procurement Strategy for Environmentally Qualified Material
by: W. Seidl, P.V. Castaldo and D. Smith

10:30 Service Qualification: The Impact of Human Performance Requirements
by: G.V. Burston and N. Carr

11:00 Main Steam Line Non-Linear Dynamic Analysis of Pipe Whip
by: M. Attab, S. Baset and W. Ajam

11:30 Structural Design of Large Vertical Spent Dry Fuel Storage Module
by: W. Ajam, A. Khan, A. Alizadeh, H. Tran and B. Canas Calderon

12:00 Close of Session

June 9, Tuesday P.M., 14:00-17:30

CNS Session 9: **Compliance and Licensing**
Chairman: R. Thomas, AECB

14:00 Application of Risk-based Value-Impact Analysis in a Nuclear Regulatory Environment
by: K. Dinnie, R. Land and M. Stella

14:30 Review of BNGSA Rehabilitation Projects and Their Focus
by: J.R. Grava

15:00 Development of a Strategic Plan for Performing Analysis in Support of an Operating Station: A PLGS Perspective
by: P.D. Thompson, D.F. Weeks and S. Alikhan

15:30 Determination of the Allowable Operating Envelope for the Point Lepreau Special Safety Systems
by: M.K. Gay, J.D. Kendall, D.F. Rennick and P.D. Thompson

16:00 Development of a Human Factors Engineering Program for New CANDU Plant Designs
by: J.S. Malcolm and J. Pauksens

16:30 NPP Technical Documentation Management – The G2 Perspective on Taming the Paper Tiger
by: P. Lafreniere

17:00 Innovations in CANDU Standard Plant Licensing
by: P.S.L. Lee and P.J. Allen

17:30 Close of Session

CNS Session 10: **Fusion Science and Technology**
Chairman: A. Natalizio, CFFTP

14:00 Highlights of Canadian Activities in Fusion Safety
by: G.A. Vivian, A. Natalizio and M.A. Wright

14:30 An EmergingTechnology for Fusion: The Spherical Pinch
by: E. Panarella

15:00 Results and Update on the TdeV Facility
by: G. Le Clair et al.

15:30 Safe Utilization of Tritium Through Proactive Management
by: W.T. Shmayda

16:00 Gas Chromograph Isotope Separation for Kernforschungszentrum Karlsruhe GmbH
by: K. Torr

16:30 Development of a Pressure Swing Adsorption Process for Recovery of Tritium from Solid Ceramic Breeder Helium Purge Gas of a Fusion Reactor
by: C. Fong, S.K. Sood, D.M. Ruthven and O.K. Kveton

17:00 300 km/s Plasma Accelerator for Fuelling
by: R. Raman et al.

17:30 Close of Session

CNS Session 11: **Darlington N12 Assessment 1**
Chairman: G.J. Field, AECL CANDU

14:00 The Experimental Program
by: G.J. Field

14:30 Fuel and Fuel Channel Inspections and Examinations
by: P. Truant and G.J. Field

15:00 Modelling of Acoustic Resonance Phenomena
by: R.E. Pauls

15:30 Return to Service Program
by: W. Robbins and D.J. Benton

16:00 Design Options
by: J. Skears, R.E. Pauls and J.M. Hopwood

16:30 Modelling of Fuel Bundle Movement in Channel Under Pressure Pulsing Conditions
by: J.H.K. Lau et al.

17:00 Close of Session

CNS Session 12: **Plant Aging and Life Extension**
Chairman: G. Grant, Ontario Hydro

14:00 Bruce NGS-A Rehabilitation Program
by: G. Grant

14:30 The Justification and Appropriation of the Bruce-A Rehab Program
by: R.O. Wells

15:00 Proposed Approach for the Management of Plant Ageing
by: W.M.C. Knowles, T.A. Andreeff, C.W. Gordon and C.I. Jobe

15:30 Development of Flush Rolled Joints for Bruce NGS A LSFCR Program
by: S. Venkatapathi, G.D. Moan, D.R. Brown and D.I. Hunter

16:00 In-Process Control of Bellows Welding During Large Scale Fuel Channel Replacement of CANDU Reactors
by: A. Ditschun and A. Filipovic

16:30 A New Fuel Channel for Bruce NGS 'A'
by: D. Brown

17:00 Fuel Channel Installation Tooling for Retubing Bruce Reactors
by: R.J. Gunn

17:30 Close of Session

June 10, Wednesday P.M., 14:00-17:30

CNS Session 13: **Thermalhydraulic Modelling and Analysis**
Chairman: M. Shoukri, McMaster University

14:00 Phase Separation Phenomenon of Dividing Steam-Water Annular Flow in T-Junctions with Downward Branch Orientation
by: F. Peng, M. Shoukri and A.M.C. Chan

14:30 An Empirical Two-Fluid Model for Critical Flows
by: W.S. Liu

15:00 A New Model for Void Fraction in Subcooled Boiling
by: H. Tang

15:30 On the Modelling of Leak Rates Through Cracks in Pipes and Tubes
by: S.I. Osamusali, K. Crentsil, R.Y. Chu and J.C. Luxat

16:00 An Experimental Study of Critical Heat Flux for Low Water in Vertical Round Tubes Under Low Pressure
by: Won-Pil Baek, Jae Wook Park and Soon Heung Chang

16:30 Onset of Channel Flow Reversal in RD-14M Natural Circulation Tests
by: P.T. Wan, W.I. Midvidy and J.C. Luxat

17:00 Analysis of Natural Circulation in Multiple Channel RD-14M Test Facility Using Test Data, CATHENA Simulations, and Simple Models
by: P. Gulshani, D. Mori, J.P. Mallory, H.M. Huynh and A. Galla

17:30 Close of Session

CNS Session 14: **Diagnostics and Data Management**

Chairman: H.W. Bonin, RMCC

14:00 Use of a Relational Database to Manage Information from Thermalhydraulic Experiments
by: R.S. Swartz, J.C. Luxat, W.I. Midvidy and D.J. Richards

14:30 Numerical Simulation of the Waterhammer Equations by the Method of Characteristics and Comparison Against Experimental Results
by: A.P. Muzumdar

15:00 Radiotherapy Compensators for an Unspecified Target Dose
by: A. Djordjevich

15:30 Reactor Noise Measurements and Signal Processing Methods for Process Monitoring and Diagnostics
by: O. Glockler and A.M. Lopez

16:00 Neutron Dosimetry and Spectroscopy Using Bubble Detectors and An Anthropomorphic Phantom
by: H.W. Bonin, G. Desnoyers and T. Cousins

16:30 A Sampling Technique for Identifying Mobile Fractions of Radionuclides in Sediments
by: M.P. Smith and M. Kalin

17:00 Point Lepreau's LAN Based Station Control Computer and Generic Monitoring System
by: H. Storey, B.K. Patterson, R. Acott, H. Thompson, A. Rosevear, D. Francis

17:30 Close of Session

CNS Session 15: **Darlington N12 Assessment 2**

Chairman: E.G. Price, AECL CANDU

14:00 Darlington NGS Unit 2 Fuel Damage Investigation
by: W.B. Stewart

14:30 An Overview of the Metallurgical Investigation into the Failure of Darlington NGS Unit 2 Fuel Bundle End Plates
by: E.G. Price

15:00 Dating the Fractures in Darlington Endplates from Oxide Thickness Measurements
by: V.F. Urbanic, M.A. Maguire and N. Ramasubramaniam

15:30 Mechanical Fatigue Simulation Testing of Fuel Bundles and Specimens for End Plate Failure
by: M. Gabbani, T. Richards and E.G. Price

16:00 Development of Fatigue Failure Criteria for Darlington Fuel Bundle End Plates
by: E.T.C. Ho, G.K. Shek, M.L. Vanderglas and M. Leger

16:30 Fuel Testing to Simulate Darlington Channel and Fuel Damage
by: E. Kohn and G. Hadaller

17:00 Close of Session

CNS Session 16: **Operator Training and Certification**

Chairman: J.S. Nathwani, COG

14:00 Towards a New Regulatory Regime for Operator Certification
by: R. Thomas

14:30 XTEND – An Expert System for Use as a Training Aid in Trip Parameter Assessment
by: P.B. Middleton, T.A. Daniels and L.J. Watt

15:00 A Fuel Cooling Basis for Critical Safety Parameter Training
by: D.B. Reeves, D.L. Stafford, J. McCarthy and S. Turner

15:30 Assessment of Training Effectiveness – A Trainer's Perspective
by: R.C. Wardman, J.J. McCarthy and S.P. Turner

16:00 Requirements for Simulator-based Testing of Candidates for Authorization
by: G.T. Bereznai, T.A. Brown, R.S. Burns and G.A. Hancock

16:30 Competency Assessment of Reactor Operator Candidates using Full-Scope Simulators – The Emerging Canadian Approach
by: G. Turcotte and A. Vachon

17:00 A Framework for Defining the Functional Role of Annunciation
by: K.Q. Guo, E.C. Davey, S.A. Russomanno and J.R.P. Popovic

17:30 Close of Session

Madame Curie: The Passion of Science

by Shayne Smith

Ed. Note: *This is the 125th anniversary of the birth of Madame Curie. In the context of our intention to mark the several anniversaries that occur this year we are pleased to present this essay by Shayne Smith, an obvious admirer of Madame Curie.*

"To her death it was science and mankind she cared for, not fame."

It was a place full of treasures, an austere remembrance of those who had changed the world. The display cases and shelves still contained the original equipment, the rooms still arranged as they had been decades ago.

The curator smiled patiently as I fumbled questions in broken French, opening the door to what had been Madame Curie's office and inviting me inside. From a desk drawer she drew a black linen smock, explaining that it was the last to be worn by the famous scientist, before her death in 1934. On a small table against the wall sat Pierre Curie's weight scale, which Marie had always kept in her office. There were scrapbooks containing the original newspaper clippings of Madame Curie's visits to the United States in 1921 and 1929, carefully prepared by her graduate students.

The chemistry laboratory had been decontaminated in the early 1980's, with much of the original experimental apparatus preserved. A geiger counter revealed that an original page from the Curies' lab notes was still measurably radioactive. Photographic film, when exposed to film, revealed Pierre Curie's fingerprint.

Located in downtown Paris, just south of the Pantheon, the Musée du Laboratoire Curie preserves the memory of one of the world's most talented and dedicated scientists, Madame Curie. The museum is housed in the famed Institute of Radium (11, rue Pierre et Marie Curie, 75005 Paris), built in 1914 as a laboratory for the study of radioactivity and the science of radium and for biological research in cancer treatment using "Curietherapy".

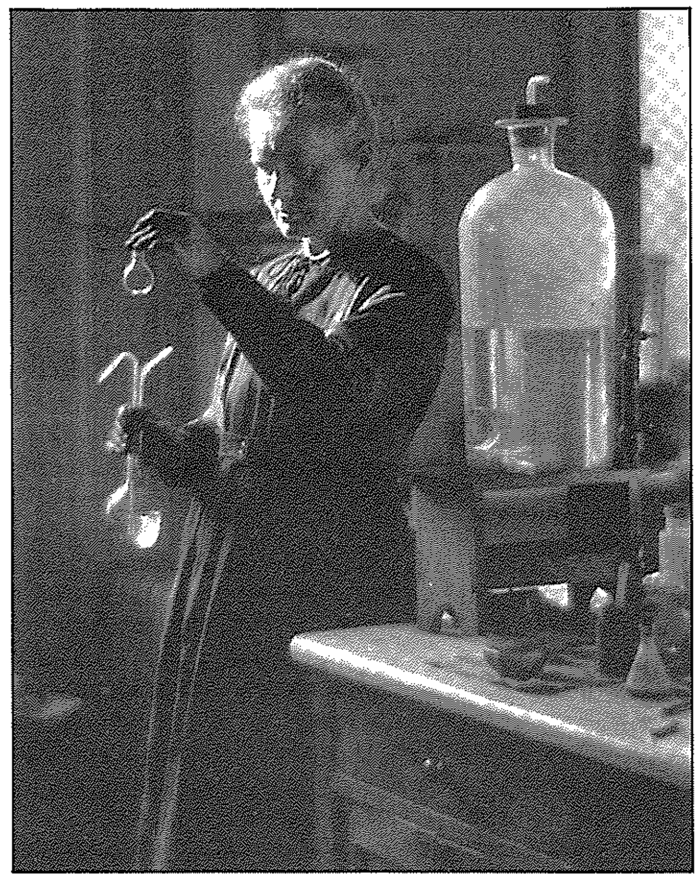
I had discovered the Institute after many hours of searching and wandering about the Paris streets adjacent to the Sorbonne. It was a visit I had always wanted to make. The elderly woman who served as the museum curator, although she could not speak or understand much English, could sense my excitement. Though lacking a common language, we each shared a curious fascination that accompanies one's personal heroes.

* * *

Marie Curie, born Marya Sklodovska in Warsaw, Poland on November 7, 1867 was the youngest of four children. Her family was extremely poor. Life in Poland was hard, and frustrated by an oppressive Russian government. By the age of eleven, both her mother and her eldest sister had died as a result of lung-related disorders.

In these seemingly insurmountable conditions, Marya pursued a dream of becoming a great scientist, encouraged by the academic success of her elder siblings and by her father, who was a teacher of mathematics and physics. Because of the limited funds available to the family, she had to wait her turn, while Bronya, her oldest sister, studied in Paris. For three years, Marya worked as a governess, studying on her own from borrowed texts on physics, math, and sociology after having already worked the long hours demanded of her.

It was not until she was twenty-four, that Marya (who would now call herself Marie) stepped off the Paris train platform on a November morning in 1891. Her dream of studying at one of the most celebrated universities in all of Europe, the Sorbonne, was finally realized. At the Faculty of Science where she was enrolled, Marie soon overcame her lack of preparatory schooling and applied herself in the most diligent manner possible, developing an extreme rigor that was to set the pace for the rest of her life.



Madame Curie at work in her laboratory at the Institut du Radium.

Marie's passion for science left no time for romance. It was her nature to present herself as plainly as possible, her customary clothing being the simplest and cheapest black or navy blue dress she could find (and of which she would have only one).

Marie met Pierre in 1894, introduced by an acquaintance who was helping Marie locate some lab space to conduct her current research. Pierre, then 35, was a teacher at the School of Physics who had, along with his brother Jacques, discovered the piezoelectric phenomenon (without it, your push-start BBQ wouldn't work!). Pierre had also developed an ultra-sensitive scientific scale called the "Curie Scale" and had conducted extensive research on magnetism.

They were similar creatures, each possessing minds of genius, and both living for scientific research and nothing else. One year later they were married, forming a partnership in which husband and wife would collaborate side by side. Although they shared a passion for bicycling and hiking through the French countryside, such jaunts would serve only as infrequent respites from their intense schedules.

Still, Marie Curie was able to achieve a balance between love, science, and maternity, a fact which is truly indicative of her miraculous character. Her first daughter, Irene, destined, herself, to be a Nobel prize winner, was born on September 12, 1897.

For her doctoral thesis, Pierre suggested that Marie perform a fundamental study of uranium rays, given the recent discoveries by Roentgen (X-rays) and Henri Bequerel (first scientist to observe phenomenon of ray emissions from uranium). Her investigations began by surveying every known chemical element, and then comparing these with mineral samples. This early work yielded curious results, suggesting that there were sources other than thorium or uranium for a more intense radiation. As evidence mounted, the Curies claimed the discovery of two new elements which they named Polonium (after Marie's native homeland) and Radium. As well, Marie coined the word "Radioactivity" to explain the phenomenon.

The element polonium proved the easiest to isolate. The more radioactive element, and by far the most illusive was radium. Pierre and Marie dedicated four years of backbreaking labour, often in intolerable working conditions, to isolate a quantity of radium suitable for analysis and to obtain its atomic weight. At their own personal expense, the Curies had shipped a ton of pitchblende residue, the byproduct of refined pitchblende ore from which uranium salts were extracted (for glass manufacture), from the St. Joachimstal mines of Bohemia. From this residue, the Curies were able to extract a decigram of radium chloride from which they estimated the atomic weight to be 225 (actual 226).

Radium was a magic element in its own right. Its discovery constituted an irrefutable argument which countered the conventional models of the physics world, previously based on defined substances and fixed elements, not a constant process of atomic transformation. Radium was beautiful to behold, for it possessed a spontaneous luminosity. Its radioactive energies were so great as to be of significant benefit in destroying cancerous tumours.

Thus a radium industry was born. The tedious extraction process made it the most valuable substance on earth, with commercial values approaching $150,000 per gram (in 1904). Pierre and Marie, who could have been made incredibly wealthy by patenting the extraction technology opted instead to freely distribute the details of the process to all who inquired, consciously deciding that their science was for everybody. "Radium was not to enrich anyone. Radium is an element. It belongs to all people."

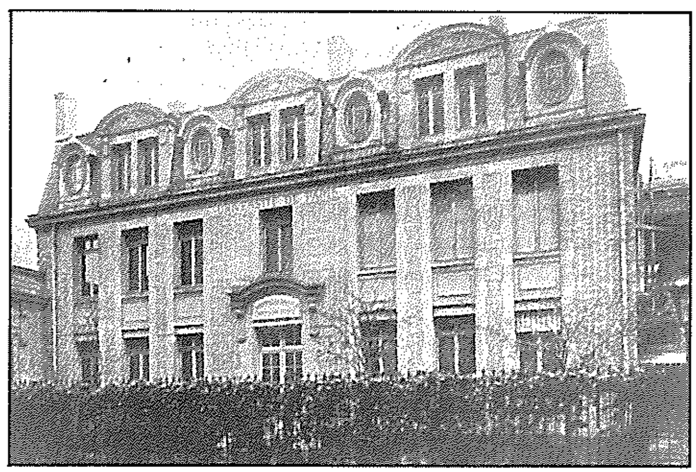
In 1903, Pierre and Marie Curie were jointly awarded the Nobel Prize in Physics with Henri Bequerel, but the resultant media attention only brought them discomfort and interfered with their work. Their second daughter, Eve, was born on December 6, 1904.

In knowing the difficulties endured by Madame Curie until this point in time, and the inestimable benefit of her scientific achievement, one would hope her life would be spared future hardship. The tragic circumstance of April 19, 1906 was one which is difficult to accept to this day. In appreciating the relationship between Pierre and Marie, it is hard to conceive of a more fitting and deserved partnership. Marie Curie's world was shattered forever when Pierre was struck down by a horsedrawn wagon, dying instantly when a wheel crushed his skull.

Following his horrible death, Madame Curie was offered Pierre's Chair at the Sorbonne, which she eventually accepted. It was the first time that a position in the French higher education system had been given to a woman.

Marie moved her family to Sceaux, outside of Paris. Widowed, with the responsibilities of parenting two children, her duties as a professor, and the burden of her own fascinating research, she continued to work incredible hours, driven to fulfil completely these aspects of her life. She often felt unwell, and sometimes had to be rescued from severe fatigue, following a collapse to the floor.

Madame Curie was an exceptional human being. In 1911, she was again awarded a Nobel Prize, this time for Chemistry. No other person in the history of the Nobel Prize has, before or since, ever received the coveted award twice. In 1914, she was named director of the newly completed Institut du Radium.



The Institut du Radium, completed in 1914, now houses the Musée du Laboratoire Curie.

With the advent of the First World War, Madame Curie decided to remain in Paris. Tales of French casualties disturbed her to the extent that she felt compelled to act, even though France was not her homeland. She created the first "radiological car", an automobile that contained a Roentgen apparatus (X-ray machine) and a generator driven by the car motor to provide the required current. From donated limousines, she created a fleet of 20 such cars and personally established over 200 radiological posts throughout the country. With the X-ray equipment at each post, doctors could more easily locate deadly shrapnel and bullet fragments. The total number of soldiers treated during the war at these stations was greater than one million.

The money from her second Nobel Prize was donated to the French government's war effort. In this respect, it is perhaps ironic that much of Madame Curie's initial recognition as a great scientist and benefactor of mankind came from beyond the French border, including much of her financial support as well. A national campaign in the United States, the "Madame Curie Radium Fund", was launched to provide her Institute with the radium required to continue its research; radium that Madame Curie had herself discovered but could not afford to purchase in any quantity. In her famous visit to the United States in 1921 where she and her daughters were treated as world celebrities, Madame Curie was presented with a gift of one gram of radium.

In the years that followed, Marie was continually dogged by the attention of the media and well wishers. Countless laurels and honours of every kind were bestowed upon her. Eventually, even the French academic aristocracy admitted her into their male dominated enclave.

In 1932 Madame Curie attended the inaugural ceremonies at the opening of the Radium Institute of Warsaw, the fulfillment of a lifelong dream to benefit her native city. The visit was to be her last time in Poland. Once again, the United States had been able to supply an additional gram of radium, which she had collected in a subsequent visit to the U.S. in 1929.

Madame Curie eventually succumbed to the damage sustained by a lifetime of handling and breathing the various forms of radium and its vapour, dying peacefully on July 6, 1934 at the age of 67. Hers was a personal sacrifice, not out of ignorance of radium's effects, but motivated by a passionate haste to achieve all that was possible within her allotted time. It was for this reason she scorned the safety precautions which she so severely imposed on her students.

* * *

Gone now from the Paris streets are the hurried steps of the tireless scientist whose triumphs shine out like the brilliance of radium itself. After bidding goodbye and thanking the kind curator (whose name I never learned) I hurried down those same streets, to join the crowds of tourists that course through Paris like a steady pulse. Our days are very different now, from those of Madame Curie, but many of the same things still frustrate the pursuit of science; inadequate funding, prejudice, politics, personal hardship, and intellectual property. It is in the context of these issues that we must appreciate the strength of scientific passion, and its power to motivate individuals in their current efforts to overcome the barriers to scientific research.

References

1. Eve Curie, "Madame Curie", Doubleday, Doran & Company Inc., New York, 1937. (Accepted as the definitive biography on Madame Curie, beautifully written with a daughter's tenderness and insight.)
2. Robert William Reid, "Madame Curie", Saturday Review Press, New York, 1974. (Recommended by the museum curator).

Critique de livre

Introduction à la cinétique des réacteurs nucléaires

D. Rozon, Professor, Institut de Génie Énergétique, École Polytechnique, Montréal, 1992.

par Ben Rouben

Au moment où ces lignes sont écrites, le livre de D. Rozon sur la cinétique des réacteurs nucléaires est à la veille d'être publié par les Éditions de l'École Polytechnique de Montréal.

Ce livre est né de notes destinées à un cours d'études supérieures en cinétique des réacteurs, cours donné par l'auteur ces dernières années à l'École Polytechnique. Le texte s'adresse donc naturellement aux étudiants en génie nucléaire. Mais il servira certainement aussi d'excellent volume de référence aux travailleurs en physique des réacteurs, qu'ils soient actifs soit en conception et analyse des réacteurs, soit en exploitation de centrale nucléaire. L'ouvrage pourrait même aider à augmenter le niveau de bilinguisme dans la communauté du nucléaire.

Le livre de Rozon est une étude approfondié de la matière. Suite à une exposition fondamentale des interactions neutron-noyau, de la fission, et des neutrons retardés, le texte fait la dérivation de l'équation de diffusion des neutrons. Il élabore ensuite la théorie des perturbations, la méthode cinétique ponctuelle, la cinétique espace-temps, la synthèse modale, la méthode quasi-statique améliorée, et la rétroaction de la température et du vide. Les techniques de calcul sont illustrées à l'aide d'exemples numériques.

Deux annexes très utiles et une bibliographie bien garnie complètent le volume. La première annexe discute des effets du xénon et du samarium – des phénomènes qui évoluent sur une échelle d'heures et de jours, par contraste avec l'échelle de secondes et minutes des transitoirés rapides qui forment le sujet principal du livre. La deuxième annexe est une étude de l'accident de Tchernobyl, y inclus un calcul de cinétique ponctuelle de la transitoire de puissance.

Rozon suit, tout au long, une approche pédagogique soignée. Les concepts sont bien définis, et les méthodes de calcul sont développées clairement et avec soin. L'enchainement des sujets suit une progression logique et naturelle.

Une particularité très utile de ce livre, du point de vue canadien : bien que le traitement théorique soit général et qu'il s'applique à toutes les filières, les propos sont illustrés à l'aide d'exemples numériques du type CANDU, en général beaucoup trop négligés dans les manuels.

En résumé, l'ouvrage de Rozon est une heureuse addition à la littérature de la physique des réacteurs, et est recommandé à tous ceux qui s'interessent à étudier la cinétique des réacteurs. L'auteur devriait penser sérieusement à produire une version anglaise du livre, qui saurait augmenter sa portée de façon significative.

Book Review

Introduction à la cinétique des réacteurs nucléaires

D. Rozon, Professor, Institut de Génie Énergétique, École Polytechnique, Montréal, 1992.

by Ben Rouben

D. Rozon's book on the kinetics of nuclear reactors is, at the time of this writing, about to be published by the Éditions de l'École Polytechnique de Montréal.

This is a textbook which has evolved from a graduate course given by the author for the last several years at the École Polytechnique. Students in Nuclear Engineering are therefore a natural readership for this book. However, it will also, according to this reviewer, serve as an excellent source volume for workers in the reactor-physics field, whether in the area of reactor design and analysis, or in the area of reactor operation. It may even contribute to a rise in effective bilingualism in the nuclear-science community!

Rozon's book is a very thorough treatment of the subject matter. Following a basic exposition of neutron-nucleus interactions, fission, and delayed neutrons, the reader is guided through the derivation of the neutron diffusion equation, perturbation theory, and the point-kinetics method to the topics of space-time kinetics, modal-synthesis techniques, topics of space-time kinetics, modal-synthesis techniques, the Improved Quasistatic method, and fuel-temperature and coolant-void reactivity feedback. The various computational techniques are illustrated with sample problem solutions.

Two very useful appendices and an exhaustive bibliography are also included. The first appendix discusses Xenon and Samarium effects in reactors – phenomena which play out on the time scale of hours and days, as opposed to the time scale of seconds and minutes pertaining to fast transients studied in the main body of the text. The second appendix is a review of the Chernobyl accident, with a sample point-kinetics calculation of the power transient.

Rozon follows, throughout, a well-organized, pedagogical approach. Concepts are well explained. Calculational methods are covered clearly and with care. Topics follow one another in a natural and logical progression.

A most useful feature of this book, from the Canadian perspective, is that although the theoretical treatment is quite general, with applicability to all thermal-reactor types, CANDU-type numerical examples are used as illustrations. These are woefully neglected in most nuclear-engineering textbooks.

In summary, Rozon's book is a most welcome addition to the reactor physics literature, and is recommended to anyone interested in learning more about reactor kinetics. Serious thought should be given by the author to producing an English version to increase the book's reach.

Speaking with High School Students

by Jerry Cuttler

Education and Public Affairs Committee

Many of us have been upset about the continuing success of the anti-nuclear movement and the media in turning public opinion against nuclear technology. The CNS survey questionnaire, sent to the members last May, indicated that over 90% of the respondents favoured greater CNS involvement in public acceptance of nuclear energy. Shayne Smith of Wardrop Engineering took the lead in forming the Education and Public Affairs Committee consisting of Shayne, myself, Troy Lassau of ORTECH, and Stephen Rogers of Ontario Hydro. We developed a strategy to visit high schools and speak with educators and students about their needs for authoritative information on nuclear matters. Troy arranged a meeting with two curriculum coordinators (for the public and separate schools) in the Halton region to communicate our willingness to help them. The feedback received revealed opportunities to satisfy school needs and, at the same time, allow the CNS to provide accurate information. So our committee began formulating a program for the schools, to start this autumn.

Holy Name of Mary High School

Meanwhile, invitations were accepted to visit schools and gain experience speaking with students. The Holy Name of Mary High School in Mississauga requested the APEO to provide an engineer on March 11, their Career Day, to speak about environmental engineering. The APEO asked me to spare an afternoon and visit the nearby school. I accepted.

It was a delightful experience. Sixty-four participants came from as many different professions, and we met each other in the teacher's lounge before the sessions. The archaeologist and I had a common acquaintance. I recognized the pilot, Tracey Darby, who used to fly King Air and Navajo aircraft to Pembroke. The marine biologist from the University of Guelph knew my niece, and I recognized the police officers who helped us set up Neighbourhood Watch. Small world!

There were three sessions with the students, each lasting 45 minutes. Three groups, of approximately 20 girls each, came to learn about environmental engineering. I followed the School guidelines (15 questions), pointing out the serious shortage of engineers in general. Those graduating in environmental engineering would have no problem finding employment in any company or as independent consultants.

As an example, I explained the environmental concerns of the principal methods of electrical generation in Ontario, and touched on the Environmental Assessment Board's Hearing on the Ontario Hydro Demand/Supply Plan. Promotional brochures from the APEO were handed out, as well as information sheets from the CNA and AECL on environmental aspects of nuclear energy. A fuel bundle and a pellet were circulated around the class. The CANDU lapel pins disappeared quickly.

The students asked many questions about nuclear energy. They knew very little about it, and could not understand what all the fuss was about. The students and school were very grateful that we all took the time to come and speak with them, and make their Career Day such a successful event.

Showdown at Clarkson High

This was definitely one of the most exciting experiences in my recent years. It started with an innocent phone call to me (at Pickering) on March 26 about speaking with students at Clarkson Secondary School on April 2. Ellyn Winters of Public Affairs later explained that one of the students wanted someone from AECL to present counter arguments to the anti-nuclear information they were receiving at the school. The student, Wallid Soliman, realized the information was inconsistent with what he had heard from his dad, who works at AECL CANDU.

Ellyn indicated I would be speaking to the Different Drummers Club, encompassing gifted students from grade 9 to OAC level. Also present would be representatives from SAGE (Students Accomplishing a Greater Environment). The director of the Enhanced Student Program, Peter Marmorek, told me later that he was a founder of Energy Probe and had introduced Norm Rubin to the movement. He studied physics at MIT, but was now an English teacher at Clarkson Secondary School.

Ellyn asked me to speak for half an hour and then answer questions from the floor. When I called Mr. Marmorek (on March 31) to request a projector, he explained that he too wanted to speak for 20 minutes, after my talk, and then open up the meeting to questions from the students. Realizing that this was now a debate, with Energy Probe speaking last, I chose the ancient Greek strategy of KYROS, LOGOS and PATHOS (credibility, logic and emotion). My objective was to stimulate student interest and induce them to take and read our information sheets and booklets.

I started by pointing out that the nuclear industry began to manage its wastes in a responsible manner long before society became so concerned about the environment. Our releases are typically 100 times below permissible limits.

The problem of radicalism in the environmental movement was identified. Its potential effects on our economy and unemployment levels were mentioned.

I spent several minutes outlining my educational background, my membership in the Association of Professional Engineers of Ontario, and my 28 years of experience in nuclear research and engineering. Then a brief explanation was given on how a CANDU works, how many we have in

Ontario and what it means to the residents. I described the waste produced and where we put it, passing around a bundle and a fuel pellet. This was compared with the wastes released from the Lakeview coal-fired plant nearby, and their effect on our environment. The excellent performance of CANDU reactors in the world was pointed out. I mentioned that the old reactors had repaid their investment and were being retubed. They would now last twice as long as before.

Then we covered the public's concern about nuclear power, identifying the goals of the anti-nukes, the contribution of the media and the failure of the nuclear industry to communicate adequately. I used slides and arguments of Sir Walter Marshall about the communication barriers between the two cultures (technical and non-technical) and the problem of vocabulary ("could" and "kill"). Analogies were drawn with airplane accidents and the adverse health effect of cigarette smoking. My presentation (with 30 slides) lasted 20 minutes.

Then Peter Marmorek got up and, for 20 minutes, he eloquently recited the Energy Probe's familiar anti-nuclear tirade. His picture was totally opposite to the information I had just provided. He was clearly and skillfully scoring debating points.

Then the questions came, most of them to me. I used the opportunity to demolish many of the Energy Probe myths with specific facts and figures. It often came down to his knowledge and experience versus mine, and I had to question his competence. Peter felt this was a "low ball" in this debating game.

The meeting attracted 20 students, and was supposed to last from 2:30 to 3:30 p.m., but it went on for another hour and a half, until 5:00 p.m. Everyone got quite excited. The debate stimulated considerable, wide-ranging discussion. I referred to the AECL and CNA information sheets and booklets we brought, and everyone helped themselves to extra copies. The CANDU lapel pins and bumper stickers were very popular. Mr. Marmorek also collected information material, and I presented him with a CANDU lapel pin.

Ellyn Winters came in part-way through the meeting and got caught up in the happening. The school principal and vice-principal also came later and saw their students in action, vigorously grilling the speakers. The principals came over afterwards and thanked us for coming to the school. They explained Mr. Marmorek's background and pointed out that he was a very capable and popular English teacher. They were very grateful that AECL had sent someone to present the other side of the nuclear issue.

The students, especially Wallid Soliman, thanked us for coming to the Different Drummer's Club and bringing the information about nuclear energy and the environment. Mr. Marmorek was also very friendly. He was happy to have this event at the school and enjoyed the debate, even though it did not go quite as he had expected.

Needless to say, I was very elated about the experience and rushed off at 5:20 to a 5 o'clock meeting in Toronto with our CNS Education and Public Affairs Committee to tell them all about this great debate.

Council Hits 100

One hundred! That is the number of meetings held by the CNS Council since the formation of the Society in 1979.

With 13 years since the first Council meeting, on 11 September 1979, this averages out to about eight meetings per year. The current Council has been right on the average.

The 100th meeting had, as usual, a full agenda covering all aspects of the Society's activities. One topic that evoked considerable discussion was the report on the recently formed Education and Public Affairs Committee. Many members expressed concern about the decreasing interest in science in high school students. There was a general feeling that CNS members can be very effective in communicating with young people on this subject. (See article by Jerry Cuttler in this issue.)

INC '93

Plans continue to develop for an International Nuclear Congress to be held in Toronto in October 1993. The CNS had earlier agreed to co-sponsor this event with the CNA.

The CNS has been asked to take on the technical sessions that are now proposed to run in parallel with the broader policy-oriented meeting. Ben Rouben, CNS secretary, is coordinating this activity.

The initial proposed set of topics is as follows:

- Reactor Safety
- Role of Regulatory Agencies
- Next Generation Reactors
- Advances in Reactor Physics
- Advances in Thermohydraulics
- Advanced Fuel Cycles
- Disposal of Used Fuel
- Uranium Mining and Processing
- Reactors Components
- Effects of Nuclear Radiation on Human Health
- Medical Applications of Nuclear Radiation
- Economics of Electrical Supply/Demand Options
- Fusion Achievements and Prospects
- Human Factors in Safety
- Steam Generators and Chemistry
- Computers in Nuclear Applications
- Irradiation Processing
- Rehabilitating Aging Reactors
- Environmental Aspects of Electrical Generation

Anyone having suggestions or comments regarding the proposed technical part of INC '93 can contact Ben Rouben at AECL CANDU.

Membership

CNS membership continues to grow. Membership chairman

Jerry Cuttler reports that there were 758 members as of the end of April.

He reminds members that they can earn a CNS tie or scarf by signing up a new member. Also, anyone attending a CNS event who subsequently joins the Society receives a $15 discount on his first year fee.

Branch News

Ottawa Branch

The recently revitalized Ottawa branch held interesting meetings in February and March and a closing dinner meeting on May 7.

On February 28 Peter Allen of AECL CANDU provided an update of the CANDU 3 project. After reviewing the steps leading to the decision to develop a new generation of CANDU in the 400 MWe range, Peter outlined the requirements adopted for CANDU 3, the design process, and the construction strategy. Many of his slides were taken from displays from the CAD system being used extensively in the design.

March 19 saw Roger Humphries, Director General Nuclear Safety at DND summarizing international initiatives in nuclear power safety. He reviewed the conclusions of an international conference held in September 1991 and the resulting moves towards an international convention on nuclear power safety.

At the May dinner meeting Terry Rummery, President of AECL Research, treated those present to a picture of the changing directions of that company.

Chairman Stefan Kupca, Terry Jamieson and Fred Boyd have agreed to continue on the branch executive for at least part of the season.

Chalk River Branch

Under the chairmanship of Aslam Lone the Chalk River Branch has had an active year. Seven meetings were held, with attendance varying from 30 to 140. A final meeting is scheduled for June 11.

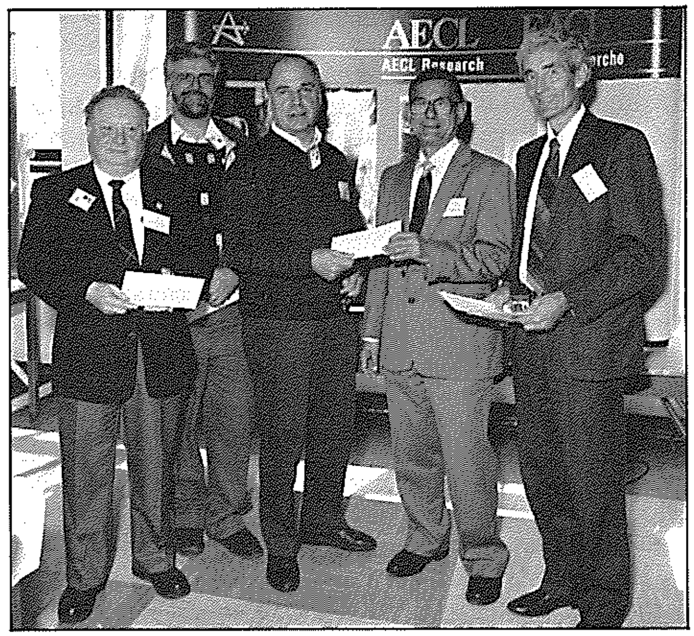
1991 Sept. 23	Hon. John Reid President CNA Global Warming and Nuclear Power
1991 Nov. 19	Tony Lees Senior Engineer, Pickering NGS Retubing of Pickering Reactors
1992 Feb. 5	Ken H. Talbot Manager, Bruce NGSA Five-Year Plan for the Refurbishing of Bruce A
1992 Feb. 13	Dr. Norm E Gentner Manager Rad. Biology, CRL A Review of the Major Features of the Chernobyl Accident
1992 March 5	Dr. J.M. Cuttler Manager Support S. Pickering, AECLC Use of He_3 Ion Chamber for Delayed Fission Neutrons (Joint with CRL Health Sciences and Services Division)
1992 March 31	Dr. Mort Bercovitch Senior Scientist NRC (Retired) Cosmic Ray Research at AECL (Site visit to Cosmic Ray Lab)
1992 May 5	Dr. Wayne Evans FRSC Professor Trent University Current Status of Ozone Layer (Jointly with CRL Public Affairs and Algonquin College)

Scheduled

1992 June 11	Dane MacCarthy V.P. Corporate Planning, OH Ontario Hydro Supply/Demand Planning

In addition the Branch organized a one-day session on writing on nuclear issues led by John McPherson and Lorna Evans of CRL, and co-sponsored the 'Science for Educators Seminar' (see below). Two submissions were made to the Ontario government.

The Branch is also providing the local organization for the 3rd International Conference on CANDU Fuel which will be held in October 1992.



CNS Chalk River - Science for Educators Seminar.

Science for Educators Seminar

by Bridget Netzel

Ninety-one teachers from Manitoba, New Brunswick, Newfoundland, Nova Scotia, Ontario, Prince Edward Island, Quebec and Saskatchewan attended the 17th annual Science for Educators seminar held at Chalk River Laboratories from Thursday, April 9, to Saturday, April 11.

The seminar provides educators with opportunities to learn about current scientific and environmental issues from scientists directly involved in research. Participants may choose from a wide variety of seminars and lab tours, meet one-on-one with scientists in their fields of interest, and participate in several social events. The primary aim of the seminar is to encourage free and open discussion of innumerable aspects of science and technology.

Twenty-three of the teachers were past participants. The large number of returnees suggests that they feel Science for Educators is a valuable professional development opportunity. One of them remarked that AECL is "to be congratulated on its efforts to advance the cause of science within the schools."

On Thursday, the educators participated in a number of pre-seminar options, including general site tours and the popular "Share an Afternoon with a Scientist" feature, in which the teachers spend time with researchers in the workplace. For this year's seminar, CRL staff from TASCC Accelerators and Development, Nuclear Physics, Neutron and Solid State Physics, Environmental Research, Radiation Biology, Health Physics, System Chemistry and Corrosion, and Physical Chemistry branches opened their doors. Employment Services branch also conducted sessions on "Careers at AECL Research", while Denny Pierce of P.J. Spratt Associates demonstrated various teaching resource materials.

Malcolm Harvey, Director, Physics Division, gave an overview of AECL Thursday evening and officially welcomed teachers to the CRL site on Friday morning. The opening plenary session featured Andy Vikis, Director, Chemistry Division, who spoke on "Chemistry Within AECL Research."

The balance of Friday's program enabled teachers to choose from parallel sessions on a wide variety of activities at CRL including: AECL's environmental science programs, microwave plasma chemical processing, mapping the DNA molecule, subatomic physics, medical radioisotope production and applications, and current physics research topics.

Activities of the day also included tours of the Nuclear Fuel Fabrication Facility, the Tandem Accelerator Superconducting Cyclotron (TASCC), the neutron radiography facilities, and the laser spectroscopy labs; demonstrations of electron microscopy equipment; an environmental research field trip; and a visit to the glassblowing shop.

Robert Ferchat, Chairman, AECL Board of Directors, delivered the after-dinner speech, "Only Connect: Science Education and the Inner World of Imagination,"at the traditional Friday evening banquet.

Saturday's parallel sessions featured presentations on particle accelerator research and applications, neutron scattering at the National Research Universal (NRU) reactor, NRU's operation, and Unit 2000, a CRL think tank.

Many contributors

Local school boards, provincial government departments of education, and teachers' associations provided much of the financial support for teachers to attend. Moreover, the New Brunswick Electric Power Commission and the Association of Professional Engineers of New Brunswick funded six teachers from their province. The Science Teachers' Association of Ontario co-sponsors the annual event with AECL Research and assists with publicity among the province's teachers.

The Chalk River chapter of the Canadian Nuclear Society also assisted three teachers from P.E.I. and Quebec with their travel expenses, and the Canadian Nuclear Association helped with the expenses of a number of teachers and also provided general financial assistance to the seminar.

The organizing committee plans to continue the seminar series next year, with a new selection of topics that reflect changing activities within AECL Research.

News of Members

As a result of the recent re-organization of Ontario Hydro's Design and Construction Branch, several CNS members have new positions.

Hugh Irvine, formerly Director, Design and Development Division, has been appointed Chief Engineer.

Brian Churchill has moved from Project Manager, In-Service Nuclear Projects to Director, Engineering and Construction Services – Bruce.

Nabila Yousef, a former CNS president, has been named as Director, Engineering and Construction Service – Pickering.

Other appointments include Don Shaw as Director, Engineering and Construction Services – Darlington and Jim Burpee as Director, Engineering and Construction Services – Thermal.

Is the Dose-Effect Relationship Linear?

Ed. Note: *In April, Dr. Bernard L. Cohen, professor of physics and radiation health at the University of Pittsburgh, presented two lectures on the topic, "Does Low Level Radiation Cause Cancer?". One was to the Toronto Branch of the CNS and the other was at AECL CANDU in Sheridan Park.*

Cohen's thesis – that epidemiological studies of persons exposed to radon and its daughters refute the widely accepted premise of a linear, no-threshold, dose-effect relationship for ionizing radiation – so intrigued two CNS members that they, independently, submitted articles on his presentation.

The first, by Jerry Cuttler, summarizes Cohen's talk and recent papers, while the second, from Keith Weaver, presents some reactions to Cohen's proposition.

Although Cohen is not the only scientist to advance this theory – see the reference in Cuttler's article to the work of Prof. Fremlin on radiation hormesis – it has not gained wide acceptance. In particular the members of the International Commission on Radiological Protection have strongly endorsed the linear dose-effect concept. As most readers are aware, the ICRP used this hypothesis as a basis for their 1990 recommendations (ICRP 60) which will lead to reductions of permissible dose by factors of 2 to 5 (see Vol. 12, No. 2, of the Bulletin*).*

Cohen Refutes Linear, No-Threshold Theory

by Jerry Cuttler

Dr. Cohen's lectures, entitled "Does Low Level Radiation Cause Cancer?" centred on dose-effect relationship for exposures to radon. This theory is used by the authorities to extrapolate the cancer risk of radon exposure from high levels, where direct data is available, to low levels encountered in homes. This theory is the basis for estimating radiation hazards and is used by the anti-nukes and the media to drive the public insane with fear of radiation and of nuclear power accidents. In the USA, billions of dollars are spent every year reducing the hazards of nuclear power; the cost increases have forced utilities to build coal-burning power plants instead of nuclear plants.

As an example of how this theory is applied, the National Academy of Sciences Committee, in 1988, extrapolated data on miners exposed to high radon levels and estimated that, if the average radon levels in US homes were 1 picocurie/litre, 14,000 Americans per year would die from radon-induced lung cancer.[1] A better way to quantify this type of risk is the Loss of Life Expectancy (LLE) which, in this case, would be 29 days for the average American. Since many millions of American homes have radon levels in excess of 12 picocuries/litre, it follows that the occupants of these homes should have a LLE of a year or more from radon.

As part of his research, Dr. Cohen supervised the measurement of radon levels in over 350,000 homes. Data were collected for 911 counties from all states except Hawaii. The records for lung cancer deaths in each of these counties were examined for men and women, and for smokers and non-smokers. Corrections were applied, for example, to account for the movement of people to other counties and states. Also considered were the different time periods, improved sealing of houses, geography, smoking prevalences, air pollution, etc.

Plotting lung cancer mortality against average radon level, over the range from 0 to 7 pCi/L, he showed a *decreasing* trend of mortality with increasing radon level. The slope for the best straight-line fit to the data is −10.1 ±2.2 for males and −2.32 ±0.61 for females. The discrepancies between the slopes of the linear theory and Cohen's results are 6.8 standard deviations for males and 5.7 for females. There was a strong *negative* correlation between lung cancer mortality rates and radon exposures. These and other results, plus lengthy analyses of errors, factors, etc., with 35 references, are written up in a report soon to be published.[2]

Prof. J.H. Fremlin of the UK considers Bernard Cohen's results to form a strong case against the non-threshold linear theory and, at the same time, an important piece of evidence in favour of the existence of radiation hormesis.[3] Hormesis is a biological term defined as the stimulus given to any organism by non-toxic concentrations of toxic substances. Fremlin believes that small amounts of radiation have a beneficial effect of "educating" the immune system. His article in *ATOM* (No. 390, April 1989) presents data on the excess cancer rates for the 91,231 survivors of the bombing of Hiroshima and Nagasaki, showing a clear *deficit* of cancer deaths for doses below 50 times background. While the numbers are small, the data clearly does not support the linear theory. Results on irradiation of mice are shown in which authors either discounted or ignored data supporting hormesis. Hormesis was also identified for salmon eggs and hatchlings. While these examples apply to low linear energy transfer (LET) radiation, Cohen's results also indicate a large degree of radiation hormesis following exposure to alpha particles, i.e., high LET radiation.

The media has refused to report or broadcast Dr. Cohen's important findings and the views of Dr. Fremlin on radiation hormesis. The probable reason is that this information is incompatible with the media's preoccupation with the dangers of nuclear radiation. The media is in the entertainment business. One point in the Nielsen rating for network evening news brings $11 million per year in increased advertising revenue.[4] They must do everything possible to attract an audience, and selecting alarming hazards is much more useful for that purpose, even though it is a disservice to society.

During his visit to Canada, Dr. Cohen autographed copies of his latest book, "The Nuclear Energy Option – An alternative for the 90s"[5]. Subsequently, he sent copies of recent papers, including "Catalog of Risks Extended and Updated"[6]. The "catalog" is most interesting. In it he identified the top three risks to be alcoholism, poverty and male-smoking with LLEs of 4000, 3600, and 2300 days respectively. When the speed limit was raised from 55 to 65 mph, it caused an LLE of 17 days. A seat belt law increased life expectancy 14 days; enforcement increased usage from 35 to 60% adding 69 days to life expectancy.

His research on occupational risks produced the interesting result that being unemployed is the most dangerous occupation. The U.S. Department of Labor estimated that a 1% increase in U.S. unemployment for one year results in 37,000 additional deaths, including 20,200 cardiovascular failures, 500 alcohol-related cirrhoses of the liver, 900 suicides, and 650 homicides. In addition to these deaths, there were 4,200 admissions to mental hospitals and 3,300 admissions to prison. The unemployed person has an average LLE of about 500 days or 1.4 years. Some of this harm is inflicted on the family and friends, and even on those who remain employed but experience stress from fear of unemployment.

The average victim of urban air pollution has a LLE of 77 days. Since coal-burning power plants are responsible for about 30% of all air pollution, they probably cause approximately 30,000 deaths per year in the USA (LLE of 23 days).

Data from the USA, Britain, Canada, Finland and France indicate that, in technologically advanced nations, the LLE due to poverty is in the range 7 to 10 years. Wealth brings health; poverty kills. For all countries, there is a strong correlation between life expectancy (from 40 to 70 years) and GNP. Education/literacy is the key factor affecting life expectancy.

It is widely belived that conserving energy would be a substantial benefit to our health (due to reduced pollution), but energy conservation measures have their own risks. For example, driving small cars increases LLE by 70 days. Reduced lighting increases accidents, crimes, falls, suicides (due to depression). Cycling is more dangerous than driving.

He estimates that the total risk from the current conservation efforts in the U.S. is probably a LLE of 50 days, while the risks of all of U.S. energy generation is a LLE of 24 days, plus 10 days due to increased estimates on air pollution.

Conservation is therefore a dangerous energy strategy if we desist from building power plants and developing energy sources in the name of conservation. This could very easily discourage expansion of industry, thereby causing increased unemployment. From historical analysis, each kilowatt per capita of energy consumption adds 30 days of life expectancy in advanced countries and 220 days in less advanced countries.

Considering the information on radiation hormesis and the data in Cohen's catalogue of risks, it is clear that the nuclear moratorium and the electricity demand management program in Ontario are inappropriate. A comprehensive strategy is needed to make the public aware of this, in order to change this policy.

References

1. National Academy of Sciences. Committee on the Biological Effects of Ionizing Radiation. Health risks of radon and other internally deposited alpha-emitters (BEIR IV). Washington, D.C.: National Academy Press; 1988.
2. Cohen, B.L.; Colditz, G.A. Tests of the linear no-threshold theory for lung cancer induced by exposure to radon. (To be published.)
3. Fremlin, J.H. Radiation hormesis. *ATOM* 390, April 1989, p. 4.
4. Cohen, B.L. The Nuclear Energy Option – An alternative for the 90s. Plenum Press, New York, 1990.
5. Cohen, B.L. Catalog of risks extended and updated. Health Phys. 61:317-335, 1991.

A Threshold for Linear Thinking?

by Keith Weaver

In this business, everybody knows about the linear no-threshold hypothesis, the postulate that risk is proportional to radiation dose at any dose level right down to zero. Most people would agree quite readily that it is an assumption and is not necessarily true. Perhaps fewer would be prepared to accept that it is demonstrably false, and that there is a large body of evidence which can be used to reject the hypothesis with a confidence that is almost absolute.

This was the straightforward message that Bernard Cohen put before the Toronto section of the CNS at its meeting on April 21. It may well have been the most significant meeting the CNS has yet organized.

Cohen's evidence is background exposure due to radon in homes. Measurements have been made to date in approximately 177,000 homes in all parts of the US. For each county in the US, the exposure data were then correlated with the corresponding mortality statistics for lung cancer (and other cancer types). The mortality data, when plotted against the exposure data, gave a curve with a negative slope for increasing exposure. The linear hypothesis would require a positive slope. The essence of Cohen's approach is simply to test the linear hypothesis. It is rejected based on the data.

Seems straightforward? Well, it's not. The linear no-threshold hypothesis is not just rejected. It is rejected by so thoroughly stunning a margin (seven standard deviations) that one really must pause and consider. This Cohen proceeded to do.

He considered the effect of smoking. He considered the effect of people not living in the same county all their lives. He considered 37 socio-economic variables, taken one at a time and in groups. He considered two alternative methods for testing the hypothesis. Both result in it being rejected with similar confidence levels. He considered removing the "retirement states" (California, Arizona and Florida) from the data. None of these modifications affected the significance of the result. In his own words, he spent two years trying to make this negative slope disappear and it wouldn't.

This is a highly interesting result, and it would seem that a vigorous airing of it is in order. The data and their manipulation ought to be subjected to the most searching independent scrutiny. If very good reasons cannot be presented to explain this situation (i.e. if the conclusion holds and the linear no-threshold hypothesis cannot be rescued) then we will be left in a rather astonishing position. The linear no-threshold hypothesis is the basis for virtually all our standards and practices in radiation protection. It says that less is always better and any amount is bad. This principle was adopted approximately 20 years ago as a conservative approach, but it seems to have become an unassailable article of faith in the intervening two decades. But what if the principle is just plain wrong? It's one thing to be wrong in the sense of being conservative, but it's something else to be wrong in the sense of being totally and unjustifiably incorrect. In which sense is the radiation protection business 'wrong'?

Rejecting an existing hypothesis is different from proposing a replacement. Could some new hypothesis be generated that does not conflict so flagrantly with what appears to be relevant data? What form would such a hypothesis take? Would it involve some threshold? The implications, both economic and political, of a threshold (at some level around average background, for example) vary from overwhelming to revolutionary. They would involve, for example, virtually every aspect of the nuclear power business, and could suggest some fundamental changes. To put it bluntly, the linear no-threshold hypothesis is an expensive one. Accepting it commits one to large societal costs. Are those costs justified? Could the resources they represent be expended more profitably (perhaps much more profitably) somewhere else?

The significance of these questions is underscored by the fact that their resolution, in its present state, rests on an assumption. In this context, a challenge having the apparent strength of Cohen's cannot simply be overlooked or dismissed. No matter what the implications, or perhaps because of them, the whole issue has to be tackled head-on.

The first priority, however, is to make sure the science is right.

Miscellany

IRPA-8

From the 17th to 21st of May, over 1,000 delegates from around the world gathered at the Palais des Congrès in Montreal for the eight congress of the International Radiation Protection Association.

The meeting was opened with short papers by Dr. Réné Lévesque, president of the Atomic Energy Control Board, and Dr. Robert Diamant, director-general of the Commission de la Santé et de la Sécurité du Travail du Québec.

This was followed by the Sievert lecture, written by Dr. Giovanni Silini of Italy who has been awarded the prestigious Sievert Award by the IRPA. As Dr. Silini was unable to attend his paper was presented by Dr. Charles Meinhold of the USA.

Silini's topic was the Ethical Issues of Radiation Protection. After discussing the basic premise of non-threshold linearity, he reviewed the three general principles of the International Commission on Radiological Protection – justification, optimization, limitation. He concluded that the present system of radiation protection is founded on sound ethical grounds, but could be improved. He advocated evolutionary progress through good research.

Close to 500 papers were included in the proceedings although less than half were presented orally – the rest were in poster sessions.

Associated with the Congress was an exhibition with over 80 companies and organizations represented.

IRPA is an association of 31 societies having over 15,000 members in 35 countries.

PBNC

The 8th Pacific Basin Nuclear Conference was held in Taipei, Taiwan, April 12 to 16. The chosen theme was "A High Technology without Borders – Nuclear."

Over 200 participants from 19 countries joined with roughly an equal number from Taiwan for the presentation of 100 papers, 10 of which were from Canada. Most of the Canadian papers were excellent overviews of specific topics. Two are reported in this issue.

Almost all of the foreign delegates were senior people and the papers and discussions reflected their perspective.

Changes at Ontario Hydro

In March, Ontario Hydro Vice-President Don Anderson announced a complete reorganization of the Design and Construction Branch.

Gone are the seven divisions, such as Design and Development, Generation, and the five separate departments, to be replaced by 10 Strategic Business Units and a Branch Integration and Services Unit.

Nine of the ten SBU's are project-oriented Engineering and Construction Services for: Bruce, Darlington, Pickering, Lambton, Lakeview, Thermal, Lines, Station/Telecommunications, Hydraulics; and the tenth is a generic Nuclear Support Services group.

Reportedly, almost all of the personnel re-assignments resulting from this reorganization were completed by mid-May.

EARP Guidelines Issued

The environmental assessment panel reviewing the proposed concept of deep geological disposal for nuclear fuel waste has issued the final guidelines to AECL for the required environmental impact statement.

The final guidelines were developed taking into account the many presentations and submissions received by the panel during its "scoping" meetings held in the fall of 1990. A draft had been issued in June 1991.

Copies of the Final Guidelines can be obtained from Guy Riverin, Federal Environmental Assessment Review Office, Fontaine Building, 200 boulevard Sacré-Coeur, Hull, Quebec, K1A 0H3 or FAX (819) 994-1469.

MIT Safety Course

MIT is again presenting its two part course on Nuclear Power Plant Safety from July 13 to July 24. The first week deals with Thermal Power Reactors and the second, General Safety Issues. One week costs $1,250 (US) and two weeks $2,200 (US).

This intensive course has been run for over two decades.

For information contact Prof. Frederick McGarry, MIT, Cambridge, MA, Tel. (617) 253-2101, FAX (617) 253-8042.

Calendar

1992

June 7-10 — **CNA/CNS Annual Conference**
Saint John, New Brunswick
contact: Dr. V.S. Krishnan
AECL-CANDU
Tel.: 416-823-9040
or Dr. K. Scott
Atlantic Nuclear Services
Tel.: 506-458-9552
or CNA/CNS office

June 7-12 — **ANS Annual Meeting**
Boston, Massachusetts
contact: Dr. W.I. Midvidy
Ontario Hydro
Tel.: 416-592-5543

August 17-18 **17th CNS Nuclear Simulation Symposium**
Kingston, Ontario
contact: Dr. H.W. Bonin
Royal Military College
Tel.: 613-541-6613
Fax: 613-547-3053

August 23-27 **Spectrum '92 – Nuclear and Hazardous Waste Management**
Boise, Idaho
contact: Dr. D.A. Knecht
Idaho Falls, Idaho
Tel.: 208-526-3627
Fax: 208-526-8632

September 20-25 **15th Congress of World Energy Council**
Madrid, Spain
contact: Dr. E.P. Cockshutt
CANWEC
Tel.: 613-993-4624

September 21-23 **Design and Review of Software-Controlled Safety-Related Systems**
Waterloo, Ontario
contact: Ms D. Del Belluz
Institute for Risk Research
University of Waterloo
Tel.: 519-885-1211

September 21-24 **5th International Topical Meeting on Nuclear Reactor Thermalhydraulics**
Salt Lake City, Utah
contact: Dr. W.I. Midvidy
Ontario Hydro
Tel.: 416-592-5543

October 4-8 **3rd International Conference on CANDU Fuel**
Chalk River, Ontario
contact: Dr. P.J. Fehrenbach
AECL/CRNL
Tel.: 613-584-3311

October 25-29 **International Conference on Design and Safety of Advanced Nuclear Power Plants**
Tokyo, Japan
contact: Prof. Y. Oka
Nuclear Engineering Research Laboratory
7-3-1 Hongo, Bunkyo-ku
Tokyo, Japan

November 15-20 **ANS Winter Meeting and concurrent meeting on Fifty Years of Controlled Nuclear Chain Reaction, Past, Present, Future**
Chicago, Illinois
contact: Dr. W.I. Midvidy
Ontario Hydro
Tel.: 416-592-5543

November 17-18 **Conference on the Management of Irradiated Nuclear Fuel**
Manchester, UK
contact: Alison Elgar
Institute of Mechanical Engineers
1 Birdcage Walk
London SW1H9JJ, UK

November ? **CANDU Reactor Safety Course**
Toronto, Ontario
contact: Dr. V.S. Krishnan
AECL-CANDU
Tel.: 416-823-9040

November 22-24 **2nd International Conference on CANDU Maintenance**
Toronto, Ontario
contact: T. Andreef
Ontario Hydro
Tel.: 416-592-3217
Fax: 416-592-7111

Calendar

1993

January 27-29 **Probabilistic Safety Assessment for 1993**
Clearwater Beach, Florida
contact: Mark Averett
St. Petersburg, Florida
Tel.: 310-825-1300

March ? CNA · CNS Student Conference
École Polytechnique, Montréal, Québec
contact: Dr. D. Rozon
Tel.: 514-340-4803

June 20-24 **ANS Annual Meeting**
San Diego, California
contact: Dr. W.I. Midvidy
Ontario Hydro
Tel.: 416-592-5543
Fax: 416-978-0193

September 5-11 **International Conference on Nuclear Waste Management and Environmental Remediation**
Prague, Czechoslovakia
contact: Radovan Kahout
Ontario Hydro
Tel.: 416-592-5384

September 12-16 **Future Nuclear Systems: Emerging Fuel Cycles and Waste Disposal Options**
Seattle, Washington
contact: Alan Walter
Richland, Washington
Tel.: 509-376-5514
Fax: 509-376-6282

October 3-8 **International Nuclear Congress – INC '93**
Toronto, Ontario
contact: Dr. W.I. Midvidy
Ontario Hydro
Tel.: 416-592-5543
Fax: 416-978-0193

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