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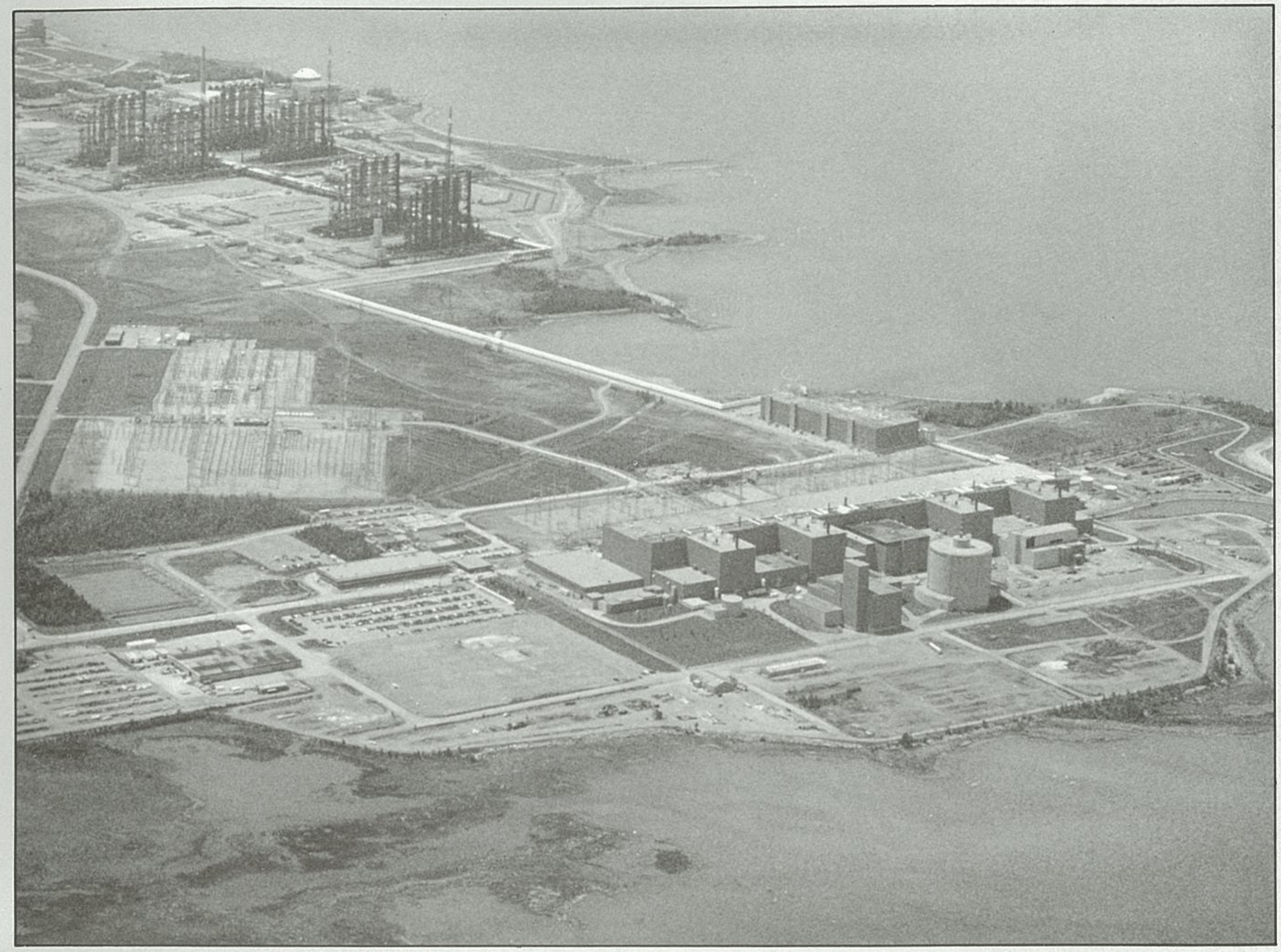

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Cover photo

The cover photograph shows an aerial view of the Bruce 'A' station with the Bruce Heavy Water Plant in the background.

The future of both of these plants was put in doubt by Ontario Hydro's recent statements.

The photograph was provided by Ontario Hydro.

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

CNS provides Canadians interested in nuclear energy with a forum for technical discussion. For membership information, contact the CNS office, a member of the Council, or local branch executive. 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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The Axe Falls

At the time of writing Ontario Hydro has just announced its sweeping changes. Perhaps by the time you read this the program will be clearer, but we doubt it.

A first reaction is that the man considered by some as a saviour of the environment turns out to be corporate hatchetman. While it is generally agreed that action needed to be taken to curb Hydro's debt some of the actions proposed appear questionable, and many are ambiguous.

The official announcement by Ontario Hydro chairman Maurice Strong stated that "no commitment will be made at this time to retube the Bruce 'A' reactors" but further stated that the "retubing option remains open" even though the "current review process will be suspended". What does that mean?

Subsequently it was made clear that no rehabilitation work would be conducted on the Bruce 'A' station and that the team that had been studying the problem and planning the work would be disbanded. That decision was made despite the strong evidence produced by the Bruce 'A' team that rehabilitating the station was the most cost-effective means of providing the 3000 MWe represented by the station. It also appears to have ignored the consequences on the Bruce energy park.

The chairman's statement went on to say that Bruce 'A' will "continue to be maintained and operated as long as safety requirements permit". However, one of the platforms for saving money is a reduction of 25% in operations and maintenance budgets. We have all seen the cost of not doing maintenance. In the early 1980's Bruce 'A' was among the top performers of nuclear plants in the world. Then the maintenance budget was cut. There is almost a direct correlation between the falling maintenance expenditures and the subsequent falling performance of Bruce 'A' over the balance of the 1980's.

Many will respond that the power of Bruce 'A' is not needed and therefore it can be allowed to be shutdown. That is true at the moment, largely because of the structural nature of the recession of the past three years which has seen manufacturing in Ontario decimated, and partly because of Ontario Hydro's expensive program to pay people not to use its product! The latter program defies logic and is a testament to the power of political philosophies over economic and technical facts.

Of major concern is, of course, what this Ontario Hydro action means for the people involved (many of whom are members of the CNS) and the viability of an on-going Canadian nuclear program. For professionals, such as CNS members, even if they accept the "golden handshakes" apparently being offered they will have great difficulty pursuing their profession and all of that talent, expertise, and, very important, their collective memory, will be lost.

Ontario Hydro officials state that the Bruce 'A' rehabilitation plans will be carefully documented and stored for future use. Does anyone really believe that it will be feasible for some completely new and inexperienced group, a decade from now, to pick up and implement those plans?

If personnel costs must be reduced would it not be worth exploring reductions in work week or income? At least the hardship would be spread more evenly and the pool of talent represented by Ontario Hydro's nuclear groups would be kept intact.

The next few months will be difficult ones for Ontario Hydro staff and for the entire Canadian nuclear industry.

On Being Politically Correct

An interesting aspect of Ontario Hydro's recent statements is the use of "politically correct" (in certain political cultures anyway) language.

As a test, count how often the adjective "sustainable" (or its noun form "sustainability") appears in the Statement by Ontario Hydro chairman Maurice Strong or the discussion paper "Hydro 21" (excerpts of which are published in this issue).

The phrase "sustainable development" first gained international prominence in the 1987 report "Our Common Future" (often called the "Brundtland report" after its chairperson). The term was never clearly defined and has been the focus of much debate in environmental and development forums, including the massive UNCED conference in Brazil last summer chaired by Strong.

Now it crops up as a major criterion for Ontario Hydro's restructuring. Perhaps it is advantageous to have ambiguous criteria – it certainly allows more "flexible" policies. As an example, the "Hydro 21" document implies a move towards short-term (read "no") planning combined with privatization, with a likely move to the use of natural gas. The fact that gas is a valuable, limited, non-renewable resource is lost in the "sustainability" rhetoric. Similarly, the obvious inconsistency between "short-term" planning (or dependence on "market place" decisions) and "long-term" resource management is conveniently ignored.

Both of the Ontario Hydro publications state that the Ontario Hydro board wishes to consult with "stakeholders" (meaning all of us in Ontario). Even if that occurs (and we remain sceptical), how can there be meaningful dialogue if the basic objectives are obfuscated by ambiguity.

David and Goliath

Hans Tammemagi

Ed. Note: The following comment was written a few months ago, well before the recent moves at Ontario Hydro. Its basic message is, nevertheless, still relevant.

We all love to cheer for the underdog. For reasons hidden deep in our psyches, the human spirit aligns itself virtually automatically with the little guy. Conversely, we are suspicious of things big. We are automatically cynical and distrustful of big corporations. They are seen as faceless, without pity or emotion, and worst of all, having the power that we all secretly fear, yet crave.

So the question quickly springs to mind – what image does the nuclear industry project? Is the nuclear industry seen as the small guy that we hold dear to our bosom; or is it seen as the big, impersonal corporation, so well parodied on the Bart Simpson show. Well, that wasn't a tough one to answer. Ontario Hydro, with over 30,000 employees and annual revenues in excess of six billion dollars is one of the largest corporations in Canada. To embellish its corporate image, Ontario Hydro chose one of the worst recessions in recent history to increase its rates about 12%. In contrast, Toronto municipal workers accepted a wage increase of 1%. No wonder Ontario Hydro public relations people are babbling incoherently and being led away by men in white coats.

The other pillar of the Canadian nuclear industry is AECL. Employing over 3000, it is one of the largest and, sadly, one of the few, major research establishments in the country. With its personnel carefully hidden away in remote locations, well removed from the mainstream of Canadian life, it is not surprising that many see AECL as a secretive, elitist and perhaps even Machiavellian organization.

The task of creating a favorable public image for the nuclear industry is akin to trying to make Ghengis Khan look like Snow White. Nevertheless, many dollars are spent annually by the Canadian Nuclear Association and its member organizations in this pursuit. Some headway is being achieved, but it is a difficult, uphill battle. Perhaps a rethinking of the basic strategy should be considered. Perhaps there is a way to distance the nuclear industry from the "big" image. Although this may seem inherently impossible, there is a very personal and "small" side to the nuclear personality – namely, nuclear medicine. It is time this character came out of the shadows and took centre stage.

Nuclear medicine is associated with individuals going to their doctors or receiving treatment at a hospital. Nuclear medicine is highly personal. It is associated with increase of lifespan, the easing of pain, the curing of disease. Almost everybody has either had nuclear medical treatment or has had a friend or relative receive such treatment. People relate to this as individuals and in a very positive manner. Whom would you invite to your son's Bar Mitzvah, the Ontario Hydro Corporate Vice President of Nuclear Engineering or your family doctor?

I suggest that the nuclear industry take steps to more closely associate itself with nuclear medicine. Ways should be sought in which to integrate the activities of health physics and nuclear medicine associations with those of the CNA and CNS. Major sessions at the annual CNA conference could be devoted to medical issues. Medical doctors and biomedical researchers could be encouraged to represent the nuclear industry in public forums. The public information program could stress that there is a very real and direct connection between nuclear power plants and, for example, cobalt cancer therapy; that the radiopharmaceuticals sold by Nordion to hospitals throughout the world are made in AECL's research reactors; that PET scans and other diagnostic medical tools are outcomes of nuclear research, and so on. What other (energy) industry has had such remarkable spinoffs?

By aligning itself with David, rather than Goliath, I feel that the nuclear industry can achieve some success in not only gaining public acceptance, but also in gaining recognition and respect for the important contributions it is making to society.

In This Issue

There is no single theme in this issue. Rather we have a collection of papers from various sources. One in particular, that by Rudy Pauls, *et al*, on acoustic modelling, is more "technical" than most but deals with a very important problem – the fuel channel vibrations in the Darlington reactors – and is interesting reading even for the non-specialist. We urge you to give it a try.

Non-technical but very relevant and having significant implications are the recent statements and reports from Ontario Hydro which are excerpted.

As a first we have a short paper from India on the use of thorium in their heavy water reactors (which are evolutions of the Douglas Point design) and hope that this will be only the beginning of overseas contributions.

A paper (or more correctly, a talk) by Colin Allan gives an overview of AECL's work on the concept for deep geological disposal of nuclear fuel waste and his arguments for proceeding with an actual facility. This is complemented by a short report on a recent federal briefing on the concept and its review under the Environmental Assessment and Review Process.

Continuing our penchant for history, we have an anecdotal recollection from Ara Mooradian, who should need no introduction.

Finally, there is a pot pourri of news and notices and, of course, considerable news of the activity of the Society.

Our new associate editor, Ric Fluke, has had a significant hand in this issue and we wish to thank him (and all you other contributors).

Ontario Hydro Statements

Ed. Note: *On 8 March 1993, the recently-appointed Chairman of Ontario Hydro, Maurice Strong, issued a statement outlining a drastic program of cost reduction and restructuring. Just two weeks earlier Ontario Hydro had issued a "discussion" paper titled "Hydro 21 – Options for Ontario Hydro", subtitled "Present Situation and Options for the Future." Since the general media has largely ignored the latter and has put their own interpretations on Strong's statement, we are printing below some excerpts from both documents, with emphasis on those sections which most impinge on Ontario Hydro's nuclear program or on the fate of CNS members.)*

Hydro 21 – Options for the Future

(excerpts)

1. Present Situation and Options for the Future

What made Ontario a successful utility in the 20th century will not be adequate for the 21st. this century's challenge was to provide cheap and reliable power to a rapidly growing Ontario.

Ontario Hydro grew in response to this challenge becoming one of the largest, most respected, utilities in the world, and the most important single organization in Ontario's economy. In the last decade of the century, Hydro faces a very different, more complex, and difficult set of challenges as it works to enhance Ontario's ability to become a world-class, competitive, energy-efficient, and environmentally sustainable economy.

Hydro is now in the process of transition.

This paper is intended to initiated discussion between Ontario Hydro and its stakeholder about options for the future

Hydro's Evolution

Ontario Hydro came into existence in 1906 as a result of public response to rapidly growing needs for electric power.

Cheap power, it was realized, was vital to the provinces's future economic development.

For the next 60 years the demand for power climbed steeply and almost without interruption. Demand doubled roughly every decade and was satisfied by building hydro-euntil the mid-1950s, by which time the major hydro sites had been developed. Hydro then turned to coal-fired stations and, by the end of the 1960s, to nuclear stations. By the end of the 1970s energy and conservation had become key issues. Growth in demand slowed and Hydro stretched out its construction programs. By the end of the 1980s demand was picking up and Hydro responded by developing a 25-year plan.

Events overtook the plan as the demand for electricity actually decreased. In January 1993 [Hydro] withdrew its application [regarding the plan] before the Environmental Assessment Board.

Future Actions

A. Short Term

Ontario Hydro has a crucial role to play to help Ontario compete economically and to do so in an environmentally sustainable way.

A main consequence of these unforeseen conditions [recession] is increased electricity rates. But there are a number of other reasons for increased rates. Ageing generating stations require more maintenance and the cost of new facilities . . . has begun to be reflected in the rates.

A Hydro task force was directed to come up with an urgent plan. These short-term initiatives are to be achieved in a way that is consistent with the long-term need to restructure Ontario Hydro for the 21st century.

B. Long-Term

Recent rate increases and declining demand may be an urgent short-term issue, but they also reflect the undeniable need for structural transformations of Ontario Hydro.

Let us look at the choices facing Ontario Hydro within the context of Ontario as a whole. It is widely accepted that Ontario must move away from its over-dependence on raw material exports towards an economy in which knowledge and technology will be the prime sources of added value and competitive advantage.

Hydro has to help Ontario use electricity – and energy generally – better by providing better energy services and showing the way to inextricably connect efficiency and sustainability.

The overall question is what sort of utility can best meet Ontario's needs for the 21st century?

2. Utility Structures to Meet Ontario's Needs

The electric power business consists of four basic components: generation, transmission, distribution and energy services. (Energy services help customers lower their energy costs through such activities as energy conservation, energy efficiency, and fuel switching.)

Ontario Hydro largely follows the traditional utility model. It is vertically integrated. Most of Hydro's electricity is sold to municipal electric utilities which distribute [it]. Hydro is publicly owned and operates as a power pool where the benefits and costs of electricity supply are shared among users.

What is a suitable structure for Ontario Hydro? A starting point is to judge options against criteria which reflect customer and community expectations. Customers tend to be concerned about cost, reliability, flexibility and service. Communities want good corporate citizenship, environmental protection, energy conservation, economic development, universality of supply, and community involvement. No structure can achieve all of these equally.

At one end of the spectrum is the large vertically-integrated and centrally-coordinated utility, with monopoly powers. At the other is a system of small, specialized, competing organizations which are only loosely connected. And within this wide range, ownership may be public, private or mixed.

Energy Services

It is possible to imagine energy services companies being run by either a private or public utility.

Distribution

Distribution is usually carried out by local or regional utilities. [It] may also be carried out by an arm of a large vertically-integrated utility. Hydro Quebec is an example.

Some jurisdictions are beginning to introduce competition at the retail level. The local utility is required to transmit electricity from rival suppliers. This process is termed giving "third-party access" (TPA) and is said to involve the "retail wheeling" of power.

Transmission

Transmission is usually seen by economists as a natural monopoly. Given current technologies, it makes little sense to duplicate the transmission network.

Access to the transmission system is therefore a key issue. In some jurisdiction, utilities are being ordered to act as a "common carrier" and allow third-party access. In markets which are moving towards more open competition, the transmission system is usually operated as a separate and distinct monopoly.

Generation

Competition can be introduced into the generation sector – facilitated by . . . third-party access to transmission services.

Introducing new supply when there is already a surplus may increase utility prices because fixed costs . . . have to be recovered over a smaller rate base. Theoretically, in a fully competitive system, a surplus could lead to lower prices.

Overall System Structure

There are many ways of linking the energy services, distribution, transmission and generation sectors. There are also many ways that public and private ownership can be mixed.

The vertically-integrated, monopoly structure maximizes economies of scale and facilitates integrated planning and operation.

The ties between the generation, transmission, distribution and energy services arms of an integrated system may be loosened to establish competitive markets. For example, a utility could maintain control over the transmission system but give others the right to generate. A further step in this direction is to break up integrated utilities into separate businesses, as occurred in England.

3. Planning for Future Needs

Like all utilities, Ontario Hydro has to forecast future electricity needs and then decide how to meet those needs. The events of the last three years have caused Hydro to rethink its approach to planning, [which] made two key assumptions. One was the decision to base planning on a 25-year horizon. The other was to plan on high growth [since] an oversupply was preferable to a shortage. A surplus of generating capacity is now forecast for the next ten years. Planning must address how to manage the surplus, how to deal with uncertainty, and how to meet future needs.

Options and Trade Offs

Integrated Plan vs "Let the Market Decide"

In many countries there is a trend toward integrated resource planning. The utility develops a comprehensive overview of resources and identifies options to meet its needs. An alternative to integrated planning is to let the market place decide.

Coordinated planning makes it easier for society to introduce policy direction into electricity planning. A market place approach . . . is likely to be more flexible and responsive to changes.

Short-term vs Long-term Perspective

A long-term perspective allows capital costs to be recovered over an extended period and allows benefits and costs to be traded off over long periods of time. At the other end of the spectrum is a short-term perspective relying on supply options with short lead times and short payback times.

A Few Large Stations vs Many Smaller Ones

Ontario's system is based mainly on large centralized generating stations. A decentralized approach would put smaller generators closer to where the electricity is used. The cost advantages of larger stations are declining. Smaller combined-cycle gas turbines have become more competitive with large coal and nuclear stations as long as gas prices remain low.

Traditional Technologies vs Promising Alternatives

Traditional supply options are hydro-electric, nuclear and natural gas of coal-fired generating stations. Alternative supply technologies, such as solar, biomass and wind have been uneconomic to date. But there could be technological breakthroughs. Fuel cells in particular show promise of becoming economic.

A Voice for the Public and Stakeholder

More public involvement earlier in the planning process can lead to better understanding, acceptance and support.

Other Key Issues

Other questions arise in utility planning. For example, should a utility pay incentives to customers to use less electricity when there is a surplus of power? Natural gas is a non-renewable resource. How does its use relate to sustainability?

4. How Should Electricity Costs Be Charged to Customers?

Attempts to restructure the way costs are recovered basically hinge on three questions: (1) Who benefits? (2) Who pays? (3) Do certain customers deserve special treatment?

The way electricity is priced today averages the relatively cheap power from older stations with more expensive power from newer ones. Pricing based on . . . marginal costs would match new demand to the costs of new power.

The Power Corporation Act at present requires that

Hydro rates should be based on average costs.

There is a link between efficiency and sustainability. A full-fledged approach to sustainability means that pricing would include all external costs. Such a strategy would have to assume that prices for all other resources would also include full environmental and social costs.

One view of sustainable development is that the financial health of our key industries must be restored. Hydro's rates could be "customized" to help industry develop or, in some cases, just survive through a difficult period.

With surplus capacity, the costs of supplying additional power is lower than our average costs. This could be taken as an opportunity to discount rates in supporting business development.

There is the issue of how promoting electricity use is consistent with energy efficiency and sustainable development goals.

Statement from Chairman Maurice Strong

(excerpts)

I am announcing today [8 March 1993] the next steps in a broad plan moving Ontario Hydro to its goal of helping Ontario become a world leader in developing an energy efficient and competitive economy, by applying principles of sustainable development.

Ontario Hydro's Board of Directors has agreed on an extensive program of cost reduction and restructuring which will freeze rates in real terms for at least the remainder of this decade, . . . and bring the increase in its debt to a halt through a program of debt reduction designed to reduce debt by at least $13 billion in the next 10 years.

These actions are designed to address the most urgent and immediate priorities of Ontario Hydro, to bring to a halt spiralling increases in its rates and its debt, and to create a leaner, more efficient, business organization. This will better serve the changing needs of our customers and contribute to the revitalization of Ontario's economy on an environmentally sound and sustainable basis.

The measures now being undertaken are based upon recommendations of an internal task force chaired by John Wilson of Ernst & Young and involve cost reductions ranging from $875 million in 1994 to $1.4 billion in 1996 as a result of measures which include:

- a further reduction of at least $10 billion in currently planned capital expenditures over the period 1998 to 2002. this is in addition to the $10 billion announced in December, effectively cutting Hydro's planned capital program in half;
- improvements to Hydro's debt/equity ratio to about 60/40;
- reductions of some 25 % in Operations, Maintenance and Administrative costs over the period 1994-1996, and . . . through 2002;
- reductions in previously planned purchases from non-utility generation of $460 million in the next three years.

Related measures include maintaining the stringent restrictions on hiring, a continued freeze on executive remuneration and severe restrictions on discretionary purchases. As a result of this program and reductions effected in the past few months, the Hydro workforce will be reduced by 6,000 to 28,000 regular staff. [This] will involve staff reductions of some 4,500 employees in addition to the 1,500 already separated in recent months. This will be effected mainly through a range of options for voluntary departure at an estimated cost of $500 million.

As part of this program, no commitment will be made at this time to retube the Bruce 'A' nuclear reactors, which will continue to be maintained and operated as long as safety requirements permit.

The Bruce Heavy Water Plant will be closed in 1994 unless export sales enable it to continue operation.

The current review process [Bruce 'A'] will be suspended and the retubing option remain open, subject to reinstatement of the review process prior to any future decision.

Hydro is currently projecting a surplus generating capacity of up to 8,500 megawatts. Additional future capacity could be made available by proceeding with the Mattagami and Niagara hydro-electric projects, through the continuing option of prolonging the life of the Bruce 'A' reactors, and by contracting for supplies of non-utility generation. These, together with the effects of demand management, are sufficient to ensure security of supply.

Accompanying and facilitating the cost reduction program is a program of fundamental restructuring to make the Corporation more cost effective, accountable and market-oriented.

The new business structure recognizes three distinct but closely related sets of functions:

- generation and delivery of electricity;
- provision of energy services;
- additional services which add value, including international services and the development of green technology related industrial opportunities.

Within this framework, each unit will be organized on a line-of-business basis with responsibility and accountability for its performance within overall corporate policies and priorities.

Some Branches and Divisions will be discontinued and those functions which continue to be required will be integrated into the respective line-of-business units. The new structure will be considered by the Hydro board at its April [1993] meeting. Implementation would begin immediately.

The primary objective of Ontario Hydro, as I see it, is to make Ontario a world class, energy efficient and competitive economy and a world leader in the transition to environmentally sound and sustainable development.

A number of other major issues . . . remain to be addressed. These have been summarized in the paper "Hydro 21," prepared for a series of round tables that is now underway.

I am convinced that the changes we will be making are both necessary and feasible and that they will produce a new Ontario Hydro better able to meet the needs and serve the interests of its customers, contribute to the sustainable development of the Ontario economy and provide challenging and rewarding careers for its employees.

Comments by OH's Don Anderson

*(**Ed. Note:** In a talk to the staff of his branch on March 10, Don Anderson, Ontario Hydro's vice-president of Engineering and Construction Services, reviewed Chairman Strong's statement of March 8 and commented on the impact of the corporate moves on his branch. Although much of his address dealt with the proposed arrangements for staff reductions, he provided some further insights into the possible restructuring of Ontario Hydro. The following excerpts from his talk concentrate on that aspect.)*

The need for change is obvious. Hydro had banked on inflationary growth that would require new capacity. We were wrong. Industrial output [in Ontario] has fallen an incredible 15% since the late 1980s. We predicted overall growth to run 3 to 4% in the nineties and demand is actually lower now than it was in 1989. We are now selling less electrical energy than we did in 1988.

Our survival depends upon getting our debt and costs under control. While some long-term planning is always necessary in the utility business, Hydro's current focus has to be short-term, on financial recovery.

The decision to hold off retubing Bruce 'A' unfortunately affects our highly skilled and effective retube team. We have no idea when there will be a need to reinstate the project. So, I have no choice but to shut down the entire project. We will document our experiences and put it on the shelf. If the project is reinstated sometime down the road we will have plenty of time to retrain and staff-up for the program.

I envision the deferral of the Bruce unit 2 rehab.

Some cuts will come through the corporate restructuring. The COG budget remains untouched.

On the positive side, [there is] the possibility of heavy water sales to Korea and Quebec. In addition, our Board approved the sale of our Pickering dry storage canisters to Lithuania.

The new Ontario Hydro will actually be three corporations – the Electricity Company; the Energy Services Company; and Ontario Hydro Enterprises. These are entirely new business structures. Most of our existing branches will be changed significantly and all branches will certainly operate differently than they did before. The majority of Engineering and Construction Services will move into the Electricity Company.

The proposed structures for the three businesses follow a line of business approach. The new organization will look like a customer-focused, business-like, cohesive team.

As we move into the new integrated business structure there [is] a significant shift in our business from construction to engineering. By and large, Ontario Hydro is getting out of the construction business. The likelihood of the corporation building a major new project is remote. Our [Engineering and Construction Services] business direction is towards engineering and project management.

Impelling Success

by Ric Fluke

It was just before the holiday season in December, 1990. Parties were being planned, decorations were being hung, and any problem at the new Darlington NGS was the last thing on anyone's mind. But at the Unit 2 reactor a fuelling machine had become stuck on fuel channel "N12" during what should have been a routine fuelling operation. Fuel had been damaged in the process, the fuelling machine could not be moved, and most troubling, the cause of the problem could not be determined. There was no option. The reactor was shut down.

Thus began one of the most publicised financial crises of Ontario Hydro. Likely causes were eagerly sought: the fuel fabricator; the fuelling machine manufacturer; over-ambitious engineers who "improved" the systems design; Mrs. O'Leary's cow; and the "mother of all scape-goats", operator error. However, after an intensive programme of evaluation, testing and data acquisition, the root cause of the problem had been confirmed. Pressure pulses induced by the rotation of the 5-vane impellers of the main heat transport pumps were amplified in the reactor inlet header and some fuel channels, causing the fuel bundles to resonate and the end-plates to fail by cyclic fatigue. The solution was to change to 7-vane impellers, thus shifting the resonant frequency to well outside the operating conditions of the reactor.

Simple enough, even though it was rather expensive. However, without confirmation of root cause, the reactors might still be shut down because more and more "wrong" solutions would be tested and rejected. The costs to ratepayers exceed $1 million per day to replace the electrical output of Darlington, not including the costs of labour, testing, materials, hardware, cutting and welding, etc. This success story, therefore, rested on the ability to quickly determine and confirm root cause; it is the result of effective deployment of engineering talent and the availability of an R&D infrastructure to respond to a crisis.

The public is well aware that a problem arose at Darlington, and that expensive repairs were made. Anything that affects electricity rates is big news these days. Some of the better informed public understand that it was an acoustic problem and that a change in pump design was the cure. But few people are aware of the "inside story" within Ontario Hydro and AECL. The details of events and analysis, between revelation of the problem and confirmation of the solution, were presented by Mr. Rudy Pauls, Senior Consultant in Ontario Hydro's Nuclear Support Services (NSS) at one of ENCON Services new Lunch-time Technical Seminars. These seminars have been organised by NSS to keep employees informed of technical issues and new developments. [See Mr. Pauls' technical report on Acoustic Modelling in this issue.]

Acoustic modelling is a relatively new and very complex field of mechanics. Explanations are best left to the experts, and readers are therefore referred to Mr. Pauls' report. A brief and simple summary of the problem is as follows. The main pumps use a rotating impeller having several vanes to circulate the heavy water. As each vane of the impeller passes a discharge pipe, it imparts a small pressure pulse into the system. The frequency of pulsations is given by the impeller's speed of rotation and number of blades. The Darlington pumps operate at 1800 RPM, and with five vanes, the pulse frequency is 150 Hz. Pulsations at 150 Hz would therefore be expected in the reactor piping. Any piping system will encounter similar pulsations, but at certain frequencies, called harmonic frequencies, parts of the system resonate. There can be several harmonic frequencies, as in a flute or an organ pipe, and different harmonics can be stimulated by applying a periodic "excitation" at one of these natural frequencies. In a reactor, the pump provides the periodic excitation and these pulsations can be amplified if the pipe lengths are "tuned" just right. The frequency at which a resonance occurs is also affected by fluid properties such as water temperature and pressure. As luck would have it, the 150 Hz pressure pulses at Darlington will cause a resonance only under a very narrow range of conditions: yes, full power operating conditions! There are no resonances at 210 Hz under the operating conditions of the reactor, and hence the attraction of the "7-vane" solution.

The harmonics of the Darlington "pipe organ" would have been a challenge for Johann Sebastian Bach, who composed Das Wohltemperierte Klavier (The Well-tempered Clavier) to demonstrate the advantages of an acoustic design change to the new "equal temperament" method of tuning. Just as Darlington underwent a design change from a 5-vane to a 7-vane impeller, the organ was modified by changing from a "7-vane" (i.e. seven long white keys per octave) to a "12-vane" (i.e. five short black keys added) keyboard. In a way, Bach confirmed the root cause of the organ's unpleasant vibrations under certain operating conditions, and demonstrated the solution. Two hundred years later, in a more complicated "pipe organ", a similar challenge arose: confirm root cause and demonstrate a solution. As explained in Mr. Pauls' report, several theories were put forth but there was not enough information to prove or disprove any of them. A special team was set up consisting of experts within Ontario Hydro, AECL and other specialists. This availability and rapid deployment of engineering talent is only part of the success story.

The other part is the availability of an R&D infrastructure, which proved to be a critical factor for success. The test facility at Stern Laboratories Inc. in Hamilton, Ontario, includes a full size Darlington fuel channel connected to a test loop. Unirradiated fuel bundles were tested under conditions simulating Darlington operation, and when a 150 Hz pulsation was introduced, the bundles were damaged in the same way as those in the Darlington reactor. This confirmed root cause. Next, a solution was needed. Again, the facility at Stern Labs was used to demonstrate the "7-vane" solution by confirming that pressure pulsations at 210 Hz would not lead to cyclic fatigue failures. Questions remained, however, because Darlington fuel bundles were damaged only in certain locations within certain channels. Would the 7-vane impeller create problems elsewhere? A detailed analytical modelling effort was needed to answer these questions before committing to a design change. This required more data that could only be derived from full-scale testing. Again, the availability of an R&D facility proved critical to success. The full size pump test facility at Ontario Hydro Research Division provided data needed to model the "source" of both 5-vane and 7-vane impellers. Based on this, and supported by separate tests at General Electric Canada Inc. and AECL's Sheridan Park Engineering Laboratory, 7-vane impellers were installed and tested in Darlington Unit 3, which was still being commissioned at the time. Thus, through the availability of human expertise and R&D facilities, root cause of a "$1 million dollar a day" problem could be identified quickly, and a solution confirmed and implemented to minimise the financial harm. This is the "inside story" to a major engineering success.

CNA Awards

The Canadian Nuclear Association annually presents awards to honour persons who have contributed significantly to the Canadian nuclear program.

W.B. Lewis Medal – to recognize Canadian or engineers who have demonstrated a high level of technical competence and accomplishment in the field of nuclear science and engineering.

Ian McRae Award – to honour an individual for outstanding contribution (other than scientific) to nuclear energy in Canada.

Outstanding Contribution Award – to recognize Canadian-based individuals or organizations that have made significant contributions in the field of nuclear, either technical or non-technical.

International Award – to recognize an individual from a country outside of Canada who has made significant contributions in the nuclear field, either technical or non-technical.

The official deadline for nominations is March 31, 1993.

For further information contact the CNA office; tel. (416) 977-6152.

ABAQUS Acoustic Modelling in Support of Darlington 'N12' Investigation

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Abstract

The occurrence of the 'N12' incident at Darlington NGS Unit 2 in December 1990 resulted in the initiation of a large investigation effort into the cause of the fuel bundle end-plate cracking by OH and AECL staff. One component of this investigation consisted of acoustic modelling of the Darlington heat transport circuit using the ABAQUS computer code.

Acoustic modelling in conjunction with in-reactor pressure measurements and out-reactor tests demonstrated that the cause of the fuel damage was acoustic amplification of pump vane-passing pressure pulsations.

Modelling with the ABAQUS code supported by in-reactor testing provided a sufficient understanding of the acoustic characteristics of the Darlington HT piping system to make an engineering decision to replace the 5-Vane impellers with 7-Vane impellers. The change to 7-Vane impellers has resulted in much reduced pressure pulsation levels in the system and elimination of fuel bundle end-plate cracking at Darlington.

The paper discusses in some detail the main considerations and assumptions made in this modelling effort.

Introduction

In December 1990, during routine on-power fuelling of Darlington NGS Unit 2 channel N12, the fuelling machine became stuck on that channel. Attempts to complete the fuelling sequence were unsuccessful. By early January, 1991, shutdown of that unit was required as the extent of fuel damage became confirmed. Following shutdown of the unit, investigations were initiated to determine the cause of the fuelling machine becoming stuck.

Examinations of fuel in the irradiated fuel bay resulted in the discovery of a number of cracks in the end-plates of fuel bundles discharged from certain channels. The cause of the fuelling machine becoming stuck was the fuel bundle disassembly caused by the failure of all supporting webs in the end plates at both ends of the downstream fuel bundle.

By May of 1991 as certain patterns in fuel damage emerged, acoustic amplification of pump vane-passing pressure pulsations was put forward as the likely cause of end-plate cracking. It was postulated that acoustic pressure pulsations in certain channels were exciting axial vibrations of the central portion of fuel within a fuel string causing fatigue failure of the most highly stressed portions of fuel bundle end-plates. The main evidence in support of acoustic resonance at that time was as follows:

- crack characteristics indicated high cycle fatigue as the end-plate failure mechanism,
- in channels with end-plate cracks, the complete fuel string exhibited a high degree of fretting wear on the end-plates, inter-element spacer pads and bearing pads,
- high frequency vibrations had been previously observed in the emergency coolant injection (ECI) lines and certain feeders and end-fittings.

As a result of this hypothesis the Darlington acoustics investigation program was initiated. The activities initiated were acoustic modelling using the ABAQUS computer code, testing at STERN Laboratories Inc. and Ontario Hydro Research Division (OHRD) and on-site testing at Darlington Unit 2. Preliminary modelling with ABAQUS indicated that strong acoustic resonances were expected under cold and hot operating conditions with the 5-Vane pump.

In-reactor (Darlington Units 2/1) and out-reactor testing conducted by May 1991, together with the acoustic modelling and other analysis being carried out concurrently, provided evidence that one of the key mechanisms causing fuel damage at the Station was acoustic resonance. In-reactor tests demonstrated that significant acoustic amplification of 150 Hz pump-generated pressure pulsations was occurring under cold and ZPH (Zero Power Hot) conditions.

In June 1991 Engineering Dynamics Incorporated (EDI), a consultant based in San Antonio, Texas, with extensive experience in acoustics, were asked to perform acoustic modelling of the Darlington NGS piping system. Similarly to the ABAQUS analysis, the EDI analysis also predicted the existence of acoustic resonances under cold and hot operating conditions. EDI's experience in modelling of acoustic behaviour in piping systems allowed a first prediction of the degree of amplification of the vane passing pressure pulsations expected in the Pump Discharge (PD) legs, Reactor Inlet Header (RIH) and feeder/channel assemblies.

It soon became clear that limitations in the EDI code would not allow the model to be expanded into a comprehensive acoustic model of the plant, which was required to explain why certain fuel channels experienced end-plate cracking and others didn't. The ABAQUS model was then developed into a more comprehensive acoustic model of the plant. This modelling demonstrated a significant correlation between predicted high pulsation channels and cracked channels in Darlington NGS Unit 2.

Also during the summer of 1991 tests were performed in the STERN 'K 12' fuel channel rig. These tests clearly showed that acoustic pressure pulsations of the order of magnitude believed to be occurring in Darlington fuel channels and at a frequency near 150 hz were capable of cracking end-plates.

Acoustic modelling performed by EDI and Ontario Hydro (OH) using ABAQUS predicted that replacement of the existing 5-Vane impellers with 7-Vane impellers would significantly reduce the acoustic amplification within the system and worst channels – particularly at the hot operating condition. These three factors, ABAQUS acoustic modelling, EDI acoustic modelling and STERN Laboratory tests were major factors in the decision to implement the 7-Vane design solution in Darlington.

In September 1991, the decision was made to replace the existing 5-Vane impellers with 7-Vane replacement impellers in all the HT pumps. The first set of four impellers arrived at Darlington NGS in March 1992.

Tests were performed in the OHRD full-scale pump loop in order to fully characterize the performance of the previous 5-Vane and the new 7-Vane impellers. These tests provided a very important input to the modelling; the source strength generated by the pump at their vane passing frequency.

In order to fully characterize the plant acoustic response with both 5-Vane and 7-Vane impellers, an extensive test program was implemented in DNGS Unit 3. Acoustic pressures were measured via fast acting pressure transducers at the end of short instrument lines (10-20 cm in length). These tests clearly showed that at ZPH maximum pressure levels in the RIH were of the order of 40 kPa with the 5-Vane impellers and 15 kPa with the 7-Vane impellers. Pressure in the most responsive feeders were measured to be a factor of 5 lower with the 7-Vane impeller than in the case of the 5-Vane impeller. The fuel string axial vibration level was found to be approximately an order of magnitude lower with 7-Vane pump operation.

In this paper, the modelling of the Darlington Heat Transport (HT) system for the RIH2 quadrant using the ABAQUS program will be discussed. This quadrant is chosen because it was fully instrumented during the Darlington Unit 3 test. The paper will highlight the modelling considerations, the finite element model, and comparison of ABAQUS predictions with Darlington unit 3 tests and the effect of changing the pump impeller from 5-Vane to 7-Vane. The role of STERN rig tests and OHRD pump loop tests in ABAQUS modelling is also briefly discussed.

The Finite Element Model

Computer Program

Three computer programs were used to perform acoustic analysis of the Darlington HT system. PATRAN, an interactive graphic program (Ref. 1), was used to develop the model; ABAQUS, a finite element program (Ref. 2), was used to do the acoustic analysis; and a user developed FORTRAN program to do the post processing.

The ABAQUS program was used for acoustic analysis of the Darlington HT system because it provided the flexibility that is required for modelling a complex HT system. ABAQUS rather than ANSYS or NASTRAN was selected for analysis as it provided 1-Dimensional (1D), 2D and 3D acoustic elements, coupled structural acoustic analysis capabilities, and greater control over problem parameters. ABAQUS does the structural acoustic analysis using finite element formulations and has both time domain (transient) and frequency domain (steady-state) solution capabilities.

In the ABAQUS formulation for acoustic analysis, the following equation is solved:

$$\frac{\partial}{\partial x}\cdot\left(\frac{1}{\rho_f}\frac{\partial p}{\partial x}\right) - \frac{r}{\rho_f K_f}\dot{p} - \frac{1}{K_f}\ddot{p} = 0 \qquad (1)$$

where p, ρ_f, K_f, and r are dynamic pressure, fluid density, bulk modulus ($\rho_f c^2$; c = sonic speed), and volumetric drag. In ABAQUS formulation, coolant flow effects are not modelled. In the Darlington piping system, the Mach number of the fluid flow is of the order of 0.01 to 0.02. At these flow rates, use of ABAQUS formulation is appropriate.

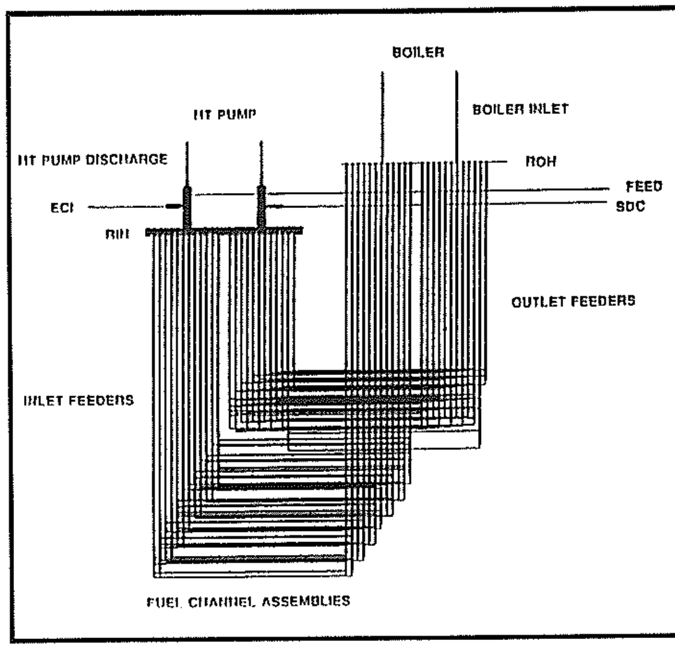

Figure 1: ABAQUS acoustic model of Darlington HT system; NW quadrant (RIH2/ROH3)

Model Bounds

Fig. 1 shows the finite element model developed for the RIH2 quadrant. Each quadrant was analyzed independently because it was assumed to be acoustically decoupled from the rest of the system. The model consisted of PD, RIH, Reactor Outlet Header (ROH), Boiler Inlet (BI), Emergency Coolant Injection (ECI), Shut Down Cooling (SDC), feed line, and 120 feeder/fuel channel assemblies. The Pump Discharge (PD) legs were modelled from the pump cutwater to RIH, SDC from PD to the first upstream valve, ECI from PD to the two upstream isolation valves, and BI from ROH to boiler inlet.

The modelling started from the pump cutwaters (See Fig. 3) because the forcing was applied as a pressure source. A P-source decouples the two sides of the load application point. Therefore, only the discharge side of the pump was modelled and the pump internals and pump suction side were not modelled.

The model was terminated at the boiler inlet with a P=0 boundary condition caused by large volume of the boiler bowl. The balance line (connected to the ROH) was not modelled as it is expected to have a small effect on the ROH response.

Element Type

The first cross mode of acoustic pressure propagation in the HT system pipes (24″ Diameter) was computed to occur at 1300 Hz. As the highest frequency of interest is 210 Hz, the wave propagation within the piping system is expected to be predominantly unidirectional (1D). For a problem of this kind, 1D linear acoustic elements, AC1D2 (Ref. 2), can adequately represent the wave propagation behaviour.

A study of the modelling of tee connections was performed in Ref. 3. This analysis showed that for the ratio of wavelength over tee dimension (diameter of the run pipe) of less than 15, results from 1D model and 2D model start diverging. In the HT system, this limit is reached for large diameter (>21″) Tee connections at 150 Hz excitation and becomes more important at 210 Hz.

The 2D elements were also required while performing numerical studies of the OHRD loop. When the loop was modelled using 1D elements, ABAQUS was able to determine the resonance for both 5-Vane and 7-Vane impellers, but for 7-Vane impeller (210 Hz), ABAQUS under-predicted the resonance temperature and over-predicted the resonance magnitude. When the Y-connection between the two discharge legs were replaced with 2D elements, or 3D elements, ABAQUS predicted both the magnitude and resonance temperature correctly.

Element Size

Numerical studies of an "organ pipe" had shown that with 0.2m long elements, the behaviour of acoustic modes with frequencies up to 300 Hz can be accurately modelled. Since the maximum frequency of interest is 210 Hz, the maximum element size was restricted to 0.2m in this analysis. For the regions of particular interest or expected to significantly affect the system response, an element size of 0.1m was used.

Material Properties

For acoustic analysis, ABAQUS requires the user to input the fluid's bulk modulus and density. Over the plant operating temperature range, 60 to 310°C, the fluid properties change significantly. Therefore, even though the forcing function is fixed, 150 Hz for 5-Vane impeller and 210 Hz for 7-Vane impeller, the HT system can cross a resonance region as temperature is changed.

Pipe Wall Flexibility

The pipe wall flexibility has an effect of reducing the effective wave speed within a pipe. To correctly account for this effect, a coupled structural acoustic analysis has to be performed. This makes analysis of the full HT system impractical with current computational technology. However, for problems in which the wave transmission is mainly unidirectional in nature, the reduction of wave speed can be obtained by decreasing the bulk modulus of the fluid. The bulk modulus of the fluid can be corrected for the pipe wall flexibility using the following formula:

$$K' = \frac{K}{1 + \frac{K}{A_f} \sum_{i=1}^{n} \frac{D_i}{t_i} \frac{A_{pi}}{E_i}} \qquad (2)$$

where K′ is the corrected bulk modulus, K is bulk modulus of fluid, A_f is the flow area of the fluid, n is the number of structural surfaces at a cross-section; and A_{pi}, t_i, D_i, E_i are the pressurized cross-sectional area, thickness, pressurized diameter and elastic modulus of structural-surface i.

The accuracy of the correction was tested using an axisymmetric coupled model for full pipe flow and annular flow. The two models give the same results (<1% difference) for frequencies up to 250 Hz.

The pipe wall flexibility correction in the channel region is significant. The channel consists of end fittings, shield plugs, the fuel bundle region, and dead spaces between shield plugs and closure plugs. The channel model was developed based on numerical studies of a 2D axisymmetric coupled structural acoustic model and a 1D acoustic model with bulk modulus modified using eq. (2). In the 1D model, the bulk modulus of the end fitting region was modified assuming that the fluid on the other side of the pipe wall does not affect the pipe flexibility. The results indicate that 1D model is adequate for modelling of the fuel channels. For the range of frequency of interest, the 1D model shows an accurate estimate of the fuel channel resonant frequencies (within 5 Hz=2%). The magnitudes predicted using 1D models are generally lower (30%). The 1D channel model was tested by comparing the ABAQUS predictions to the STERN Loop tests for empty fuel channel and channel filled with rigid fuel bundles. The channel was modelled from inlet grayloc to outlet grayloc and experimental dynamic pressures were applied at the two ends of the model. The ABAQUS results are especially good for empty channel tests which indicate that ABAQUS has appropriately modelled the end fitting (see Fig. 2). For tests with rigid fuel bundles, ABAQUS results are reasonably good for the hot condition. In the fuel bundle region, the acoustic wave may be affected by the fuel bundles in the channel. However, since the response in the channel is approximately correct, a reasonably good result for the response magnitude in the channel region is expected when the full feeder/channel assembly is modelled.

Stress Stiffening

During operating conditions, the piping has a static pressure of 10 MPa. This pressure will stiffen the pipe wall due to stress stiffening. The effect of stress stiffness in the acoustic analysis is to modify the Modulus of Elasticity (E) used for the pipe wall flexibility. The regions most susceptible are the pressure

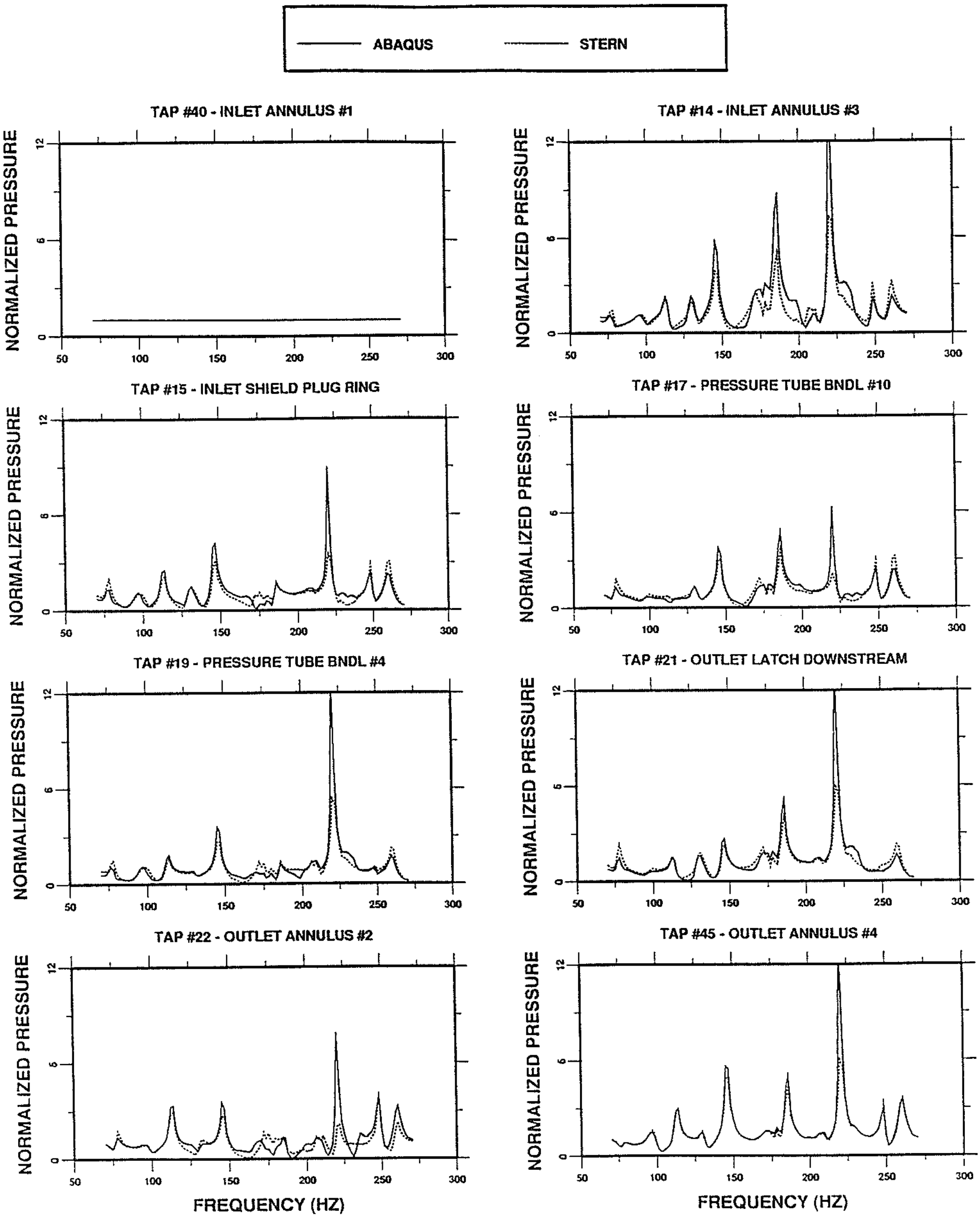

Figure 2: Acoustic response of STERN test fuel channel assembly with no fuel bundles at 290° C; ABAQUS model results versus test results (reference pressure transducer: TAP #40)

tube and end fitting section of a fuel channel as they have high diameter/thickness ratios and low E's. As this effect is considered to be secondary, it was not considered.

Damping

In the ABAQUS program, acoustic damping is applied using volumetric drag (r). It is a single term used in ABAQUS to account for dissipation of acoustic energy (due to viscous losses, thermodynamic losses and any other losses in the system). In estimating these losses, use of coefficients developed for steady state static flow is not appropriate. Experiments have to be performed to estimate the loss terms for the appropriate thermal-hydraulic conditions.

ABAQUS simulations of the resonant conditions at STERN rig, OHRD pump loop and Darlington Unit 3 have shown that the volumetric drag depends on cross-sectional areas, mode shape, temperature, wetted surface area, and flow rate. Damping increases with increasing flow velocity and wetted surface area and decreases with increasing temperatures.

Volumetric drag affects the resonant response of the system by controlling the magnitude of response. In evaluating the response, what is important is cumulative volumetric drag in the total system. The cross-sectional areas and mode shape are important in estimating the effective cumulative volumetric drag. For sections of piping with no flow (ECI & SDCS), the volumetric drag is small. The response of these sections is controlled by the damping in the rest of the system. In these sections, a low drag of r = 1500 kg/m3-s was used.

For large diameter piping, r = 12000 kg/m3-s at 265°C was used. The volumetric drag in this section was estimated based on OHRD loop tests. Small perturbations of the volumetric drag values does not significantly affect response as the feeders provide the bulk of damping to this system.

For feeders, heterogeneous volumetric drag was used. The volumetric drag was changed on the basis of temperature, cross-sectional areas and wetted surface area. The volumetric drag values were estimated based on simulations of STERN experiments.

Loading (Pump Impeller With Odd Number Of Vanes)

Fig. 3 shows a schematic of a Darlington pump which is a double-volute, double discharge pump with two cutwaters. The impeller rotates at 30 Hz (1800 rpm). A dynamic pressure pulse is generated when a vane passes a cutwater. This results in 150 Hz or 210 Hz pressure pulsations for a 5-Vane or 7-Vane impeller, respectively.

When a vane passes a cutwater, the opposite cutwater is between two vanes and therefore the pressure at this cutwater is out of phase with the pressure at the other cutwater. This kind of loading can be modelled using an anti-symmetric loading at the cutwaters. An anti-symmetric loading was applied at the pump cutwaters using sinusoidally varying peak pressure of P=+/-1 at the cutwaters. These values of pressure amplitude at the cutwaters were used in Darlington NGS acoustic modelling.

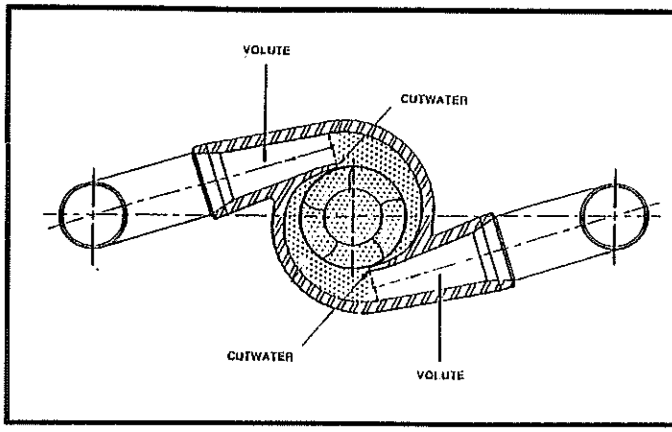

Figure 3: Schematic of Darlington 5-Vane impeller HT pump (top view)

To estimate the actual pressures at the cutwaters, simulations of experiments at the OHRD pump test loop was performed. ABAQUS results at off-resonance conditions yielded cutwater pressures of 21 kPa for 5-Vane and 14 kPa for 7-Vane impellers.

Modelling Uncertainties

The PD/RIH sub-assembly of the system goes into resonance at a certain operating range. These resonances are affected by the lines attached to these piping. ECI, SDC, feed line and feeders are attached to the PD/RIH sub-assembly. The effect of an attached line is significant if the flow area of the attached line is significant compared to the flow area of the run pipe. The ECI & SDC line have 12" and 8" diameter and significantly affect the resonance. These lines contain stagnant fluid which makes it difficult to estimate the temperature distribution in these lines. Therefore, acoustics of these lines can only be modelled approximately. The observed variation in resonant temperatures between quadrants and units of Darlington are believed to be due to variations in the ECI/SDC lengths and/or temperature of the ECI/SDC lines.

The results are sensitive to the lengths used in the analysis. For example, a difference of 0.2m in the inlet and outlet feeder lengths for a typical feeder-channel assembly can result in a 2 Hz difference in the channel resonance frequency in the 150 Hz range. High response in the feeder is obtained when the feeder resonance and header resonance are tuned. A 2 Hz error in computed feeder/channel frequency can result in improper estimate of feeder tuning and thereby channel pressures. As channel ranking for susceptibility to cracking is based on maximum pressure in the channel, improper estimate of channel pressure can lead to incorrect ranking of channels.

The fluid properties within the fuel bundle region are dependent on the fuel bundle flexibility. In addition, as the fuel gets irradiated, its flexibility changes. This change in fuel flexibility is expected to have a minimal effect on the header resonance but will affect the feeder/channel resonance.

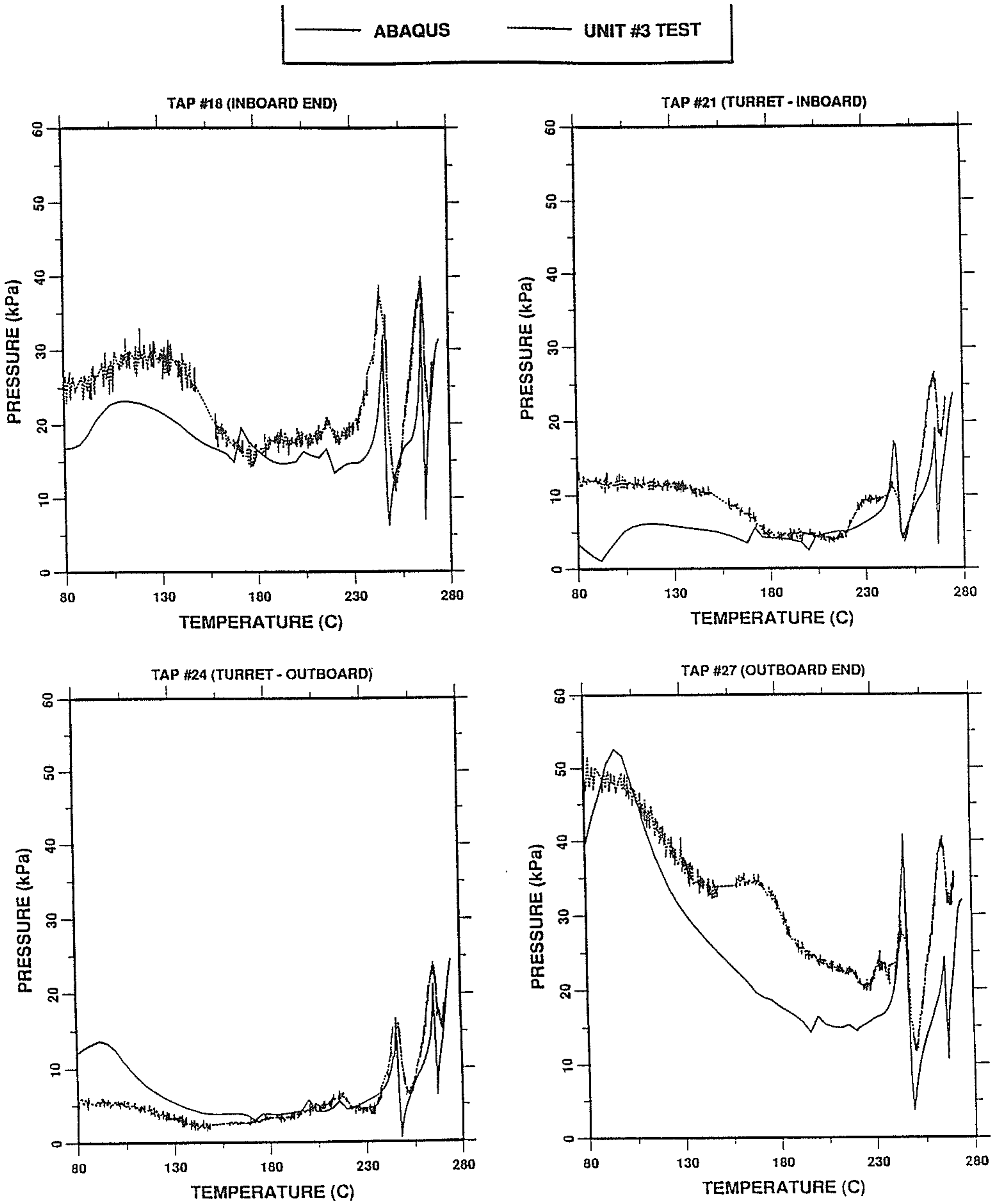

Figure 4: Darlington RIH2 acoustic response; 5-Vane impeller HT pump; ABAQUS model results versus Unit 3 test results

Analysis and Results

The analysis was done in two parts, which address different objectives. The objective of the first part was to predict the operating range at which the RIH goes into resonance and to estimate the magnitude of the resonance. This analysis was used to evaluate the effect of design changes on the system response; e.g., 7-Vane impeller, resonators and stubs.

The second part of the analysis was to predict pressures in the channels and to rank the channels based on maximum pressure within the channel. For the second part of the analysis, measured pressures in the header from Darlington Unit 3 test were used. The channels were then ranked based on calculated acoustic pressure amplitude.

The second part of the analysis was feasible because each feeder (channel) assembly is a decoupled system with RIH header acting as a P-source and ROH header acting as P-sink. Decoupling of feeder/channel permits a more reliable method of estimating pressures in the channel as it properly accounts for tuning of feeder-channel frequency to the actual measured response in the RIH.

5-Vane Impeller

Fig. 4 shows the trends in measured versus predicted values of pressure in the RIH as the temperature changes. There are two temperature regions of resonance: cold (80-150ĩC) and hot (240-280ĩC). The hot condition resonances have three peaks. The numerical analysis seems to indicate that these peaks in the hot conditions are because the PD/RIH has a resonance at 270°C and the ECI line and SDC lines introduce additional resonances at 245°C and 265°C due to closely coupled modes. There are minor differences in the resonant temperatures obtained experimentally and those predicted by ABAQUS. These differences may be due to modelling uncertainties. The analysis is able to capture the amplification of pressures in the RIH.

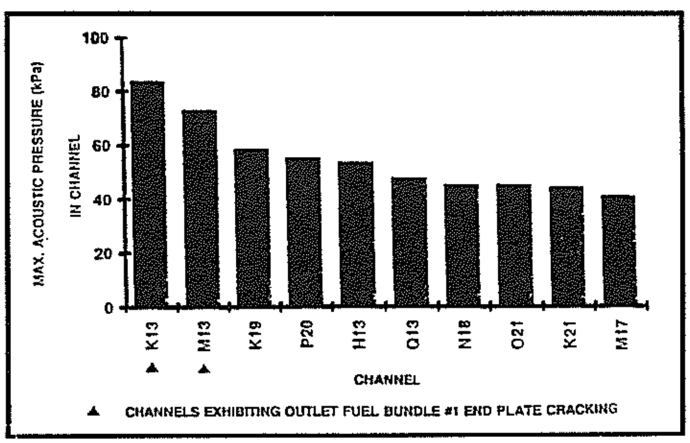

Figure 5: Ranking of Darlington NW quadrant fuel channel assemblies (served by RIH2/ROH3) based on maximum acoustic pressure in channels at 265° C under 5-Vane impeller HT pump operation

Fig. 5 shows the ranking of the 10 most responsive channels served by RIH2 for ZPH conditions. The pressure values in RIH were scaled with respect to the test values. The ranking was based on the maximum pressure pulsation magnitude in a channel (Grayloc to Grayloc). Maximum pressure in all 120 channels were considered. The top 10 responsive channels within +/-5C° of the ZPH temperature (265° C) were selected. All channels connected to RIH2, that have cracked bundles (K13, M13) have been captured by the top ranked channels. This observation confirms the hypothesis that the failure is due to acoustic pressure pulsation.

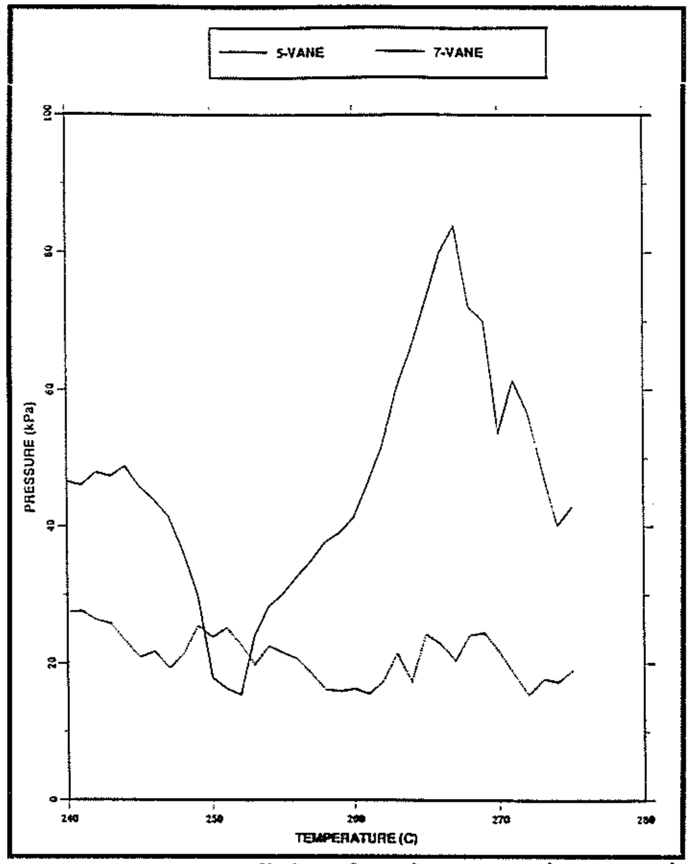

Figure 6: ABAQUS prediction of maximum acoustic pressure in Darlington NW quadrant fuel channels at zero power hot condition (265° C)

7-Vane Impeller

Fig. 6 shows a plot of maximum pressure in the fuel channel for the 5-Vane and 7-Vane impeller. The 7-Vane impeller gives ¼ the pressure in the channels as compared to the 5-Vane impeller. This result is consistent with the plant operating experience, i.e. no end plate cracks observed with the 7-Vane pump operation.

Conclusions

1. Modelling performed with the ABAQUS code in conjunction with in-reactor and out-reactor testing developed a good understanding of the fuel failure mechanisms that led to the 'N12' incident at Darlington.
2. The multiple high amplitude, sharp resonant acoustic responses observed under 5-Vane impeller hot operating conditions were determined by ABAQUS modelling to be due to the coincidence of an acoustic resonance in the PD/RIH piping system, tuning in with acoustic resonances in the ECI and SDC lines.
3. Modelling with the ABAQUS code supported by EDI acoustic modelling and in-reactor testing provided a sufficient understanding of the acoustic characteristics of the Darlington HT piping system to make an engineering decision to replace the 5-Vane impellers with 7-Vane impellers.

4. The acoustic response of individual feeder/channels becomes large when both the acoustic resonance of that feeder/channel and the header resonance occur at the same temperature, *and* the feeder is connected to a high pressure region in the header.

This analysis was performed at zero power condition. At power conditions, the PD/RIH temperature does not change significantly. As resonance in this sub-assembly is based on sonic speeds which is a function of temperature, the resonance in the PD/RIH leg is not expected to change significantly as the power level in the system changes.

The Darlington Unit 3 tests have shown that the change from 5-Vane impeller to a 7-Vane impeller has reduced the pressure pulsation in the RIH by a factor of 3 and in the most active channel by a factor of 4 at Zero Power Hot conditions. No fuel end-plate cracks attributable to 7-Vane operation have been observed to-date.

Acknowledgements

The authors would like to thank everyone involved in the Darlington N12 Investigations, especially those involved in the Darlington, Stern Laboratories Inc. and Ontario Hydro Research Division pump loop test programs. We appreciate the high level of technical computing services provided by Mr. S. G. Fabbri and Mrs. L. Russell in support of this work, and Drs. A. P. Muzumdar and J. C. Luxut for valuable technical input.

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International Congress Scheduled for October

Ray Burge

Three years of planning will come to fruition in October this year when the International Nuclear Congress (INC93) is held in Toronto. The Congress will bring together world leaders, decision makers from business and government and nuclear practitioners to explore the issues which must be resolved to launch the second nuclear age.

The congress format provides maximum opportunity for discussion and debate with a list of distinguished speakers and panelists. Plenary Sessions will examine the major policy issues facing the industry and a series of Technical Sessions will provide pertinent data and information to delegates which will be useful in their professional work.

INC93 will incorporate an exhibition, held in an exhibit hall adjacent to the conference rooms so that ready access is provided for all delegates to the manufacturers exhibits.

INC93 will be held Oct 3-6, 1993 at the Sheraton Hotel & Towers in Toronto. A General Program will be distributed to all members of CNA and CNS shortly. Meanwhile, further information can be obtained by calling the CNA Office (416) 977-6152 or John Boulton, (416) 823-9040.

World Energy leaders to address INC93

Keynote addresses at INC93 will introduce the sessions and give delegates an overall perspective of the thematic content of the program. Henrik Ager-Hanssen of Norway will delineate the future energy needs of the world in his opening. His address will be followed by a look at the environmental and social impacts of those needs by James Hann, Scottish Nuclear Chairman.

The economics and financing aspects will be dealt with by Helga Steeg, The Executive Director of the International Energy Agency, while Dr. Allan Bromley, former Advisor to President Bush for Science and Technology will discuss the technological developments which are likely to influence industry prospects.

INC93 will squarely face nuclear issues

The heart of the Congress consists of four sessions which examine the environmental and social implications of nuclear energy. These sessions will examine reactor safety, waste management, economics and financing and public acceptance. In morning presentations experts will discuss the environmental and social implications of these subjects in a series of papers which set the stage for Round Table discussions which take place in the afternoon.

The Round Tables consist of carefully selected panels of experts, representing various viewpoints on these controversial, crucial and imminent energy issues. The format is such that both the platform experts and the audience can interact to generate insights which can be developed into new avenues of thought and initiatives for action.

Eminent speakers will address long term strategies

A highlight of the Congress program will be a Strategic Energy Session which will take place on the final day. This session is patterned after that of the highly successful World Energy Congress in Montreal in 1989. The purpose is to provide the audience with a basis for long range strategic thinking and planning.

The subject chosen is "What strategies could meet Global Energy Needs Through the 21st Century, Consistent with Environmental and Resource Imperatives? *What Role for Nuclear Energy?*"

Two very different viewpoints will be presented, both by respected experts who are recognised world-wide. W. Kenneth Davis, former Deputy Secretary of Energy USA and Professor Jose Goldemberg, former Brazilian Secretary of State for the Environment are the speakers so that this event promises to be a far-ranging and significant discussion.

Partial Thorium Loading in the Initial Core of Kakrapar Atomic Power Reactor

M.R. Balakrishnan*

1. Introduction

The first unit of the 2×220 MWe Pressurized Heavy Water Reactor nuclear power station at Kakrapar has become critical. For the first time in the world, a heavy water power reactor has become critical with part of the initial core loaded with thorium oxide.

In a heavy water reactor, if the initial core has natural uranium fuel loaded in all the channels, and has no substantial quantity of neutron absorbing material spatially distributed specifically for the purpose of neutron flux flattening, the neutron flux and consequently the heat generation, will be maximum at the centre of the core. If no effort is made to flatten the power distribution in the radial direction, the maximum power rating of the reactor will be limited by the highest permissible channel power at the centre of the reactor. Hence, it is essential that the power distribution in the reactor is made as flat as possible so that as large a number of fuel channels can generate as high a power as possible, without any channel power exceeding the maximum permissible limit.

When the fuel burn up in the reactor core reaches equilibrium condition, a certain degree of power flattening is brought about by having two zones in the reactor core, with the inner zone having an average fuel burn up substantially higher than the average fuel burn up in the outer zone. While the fuel in the inner zone has a discharge burnup of about 10,200 MWD/T, the rest of the core has an average discharge burnup of about 5,350 MWD/T. The fuel with a higher burn up in the central zone has a higher neutron absorption cross-section which nullifies the effect of the natural tendency of the neutron flux to peak at the centre. However, in the initial core, this strategy is obviously not feasible. In the heavy water reactors built at Kalpakkam in Tamil Nadu, Rana Prathap Sagar in Rajasthan and Narora in Uttar Pradesh, power flattening in the initial core was achieved by loading the required quantity of depleted uranium, instead of natural uranium, in some of the central channels.

2. Thorium Loading

The Reactor Engineering Division of Bhabha Atomic Research Centre (BARC) proposed that thorium fuel bundles could be loaded in the initial core, instead of depleted uranium bundles, in order to achieve power flattening. Thorium has a higher neutron absorption cross section than either natural or depleted uranium. Consequently the total number of thorium bundles needed is substantially lower than the total number of depleted uranium bundles required. In addition to these advantages, the production of PHWR fuel bundles is not affected. Fabrication of depleted uranium bundles disrupts the normal operation of Nuclear Fuel Complex at Hyderabad, since depleted uranium bundles are fabricated using the same facilities which are used for the fabrication of natural uranium bundles.

Although the higher neutron absorption by thorium helps in reducing the total number of thorium fuel bundles required, the locations in which thorium bundles are loaded have to be chosen very carefully. Loading fuel bundles with higher neutron absorption cross section at any space point in the core leads to more depression of neutron flux at that point and in its neighbourhood. If the neutron flux at a point where a safety rod is located is depressed, the reactivity worth of the safety rod gets reduced. In a heavy water reactor, the total worth of all the reactivity mechanisms is not much higher than the minimum required. This is so partly because of the desire to minimise the total number of penetrations in the calandria vessel. As such, the locations in which the thorium bundles are to be loaded have to be critically optimised in such a way that the requisite power flattening in the initial core is achieved without any adverse impact on the reactivity worth of the safety mechanism throughout the time until the core reaches equilibrium stage. Using a Dynamic Programming approach, Reactor Engineering Division worked out a satisfactory configuration for loading the thorium bundles.

The Narora reactors had 384 depleted uranium bundles in the initial core, while the Kakrapar reactor has just 35 bundles of thorium oxide. In the Narora units, in the initial core, each of the 48 channels in the central region had 8 depleted uranium bundles. In the Kakrapar reactor core, the 35 thorium bundles have been loaded in 35 different channels with no channel having more than one thorium bundle.

3. Safety Systems

The safety system in the Kakrapar reactor, as in the case of the Narora units, consists of a primary shut off system of fourteen mechanical shut off rods, and a secondary shut down system of twelve liquid poison tubes.

Each of the 14 primary shut off rods contains cadmium sandwiched in stainless steel. These shut off rods of 7.65 cm diameter move in zircalloy guide tubes of 9.1 cm diameter. All the guide tubes are in the vertical direction passing through the space between the horizontal fuel channels. The 14 rods constituting the primary shut down system together have a reactivity worth of about 36 milli-k in the initial core, and about 33 milli-k in the equilibrium core. It is the reactivity worths of 36 and 33 milli-k which had to be maintained with the loading of thorium bundles in the initial core. These mechanical shut off rods are normally outside the core when the reactor is operating.

In the secondary shut down system of liquid poison, neutron absorbing material boron in the form of lithium pentaborate solution in heavy water, having about 20 gm of

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boron per litre of the solution, is injected into the zircalloy tubes from the bottom when the secondary shutdown system is to be actuated. The secondary shut down system comes into action only in the event the primary shutoff rods do not get inserted into the reactor core within the stipulated time when the situation demands that the reactor is to be shut down. The 12 liquid poison tubes have a joint reactivity worth of about 32 milli-k in the initial core and about 28 milli-k in the equilibrium core. The reactivity worth of the secondary shutdown system also is to be unaffected by loading thorium loading in the specially chosen configuration. These liquid poison tubes also pass vertically through the reactor core.

It needs to be pointed out that the reactivity worth of either of these two shutdown systems depends on a variety of conditions such as the core burnup, whether any other reactivity controlling mechanism is present in the reactor core or not, etc. What needed to be ensured before loading thorium in the initial core was that the presence of thorium in the recommended configuration has no adverse effect on the reactivity worths of these shutdown systems.

4. Regulating Systems

In addition to the primary and secondary shut down systems, there are four positions where adjuster rods can be moved, one from the top and one from the bottom at each of the four locations. The 8 adjuster rods, made of cobalt, together have a total worth of about 8 milli-k. Unlike the primary and secondary shutdown systems, the adjuster rods are normally inside the reactor core when the reactor is operating. When the reactor is running there is production of xenon, which absorbs a large number of neutrons and is termed a neutron poison. It is produced from the radioactive decay of Iodine 135 produced in fission. While the reactor is running, xenon gets destroyed too, due to neutron absorption. Once the reactor is shut down, during the initial period xenon generation is continued. The adjuster rods are withdrawn, and thereby positive reactivity is inserted into the core, in order to overcome the negative reactivity due to the xenon poison. If the reactor is not restarted within about 30 minutes after it is shut down, build up of xenon would have gone beyond the value which can be nullified by withdrawing the adjuster rods. Then, nothing can be done except wait for about 36 hours when the xenon concentration would have gone down to radioactive decay.

Two locations have two regulating rods each, made of cobalt, one moving from the top and the other from the bottom. The four regulating rods together have a total worth of about 4 milli-k. During reactor operation the regulating rods are partly inside the core, and the level to which they are inserted is changed for regulating reactor power and neutron flux shapes.

Two other locations have shim rods made of borated stainless steel. Like the adjuster rods and regulating rods, each location houses two rods, one inserted from the top and the other from the bottom. The four shim rods have a total worth of about 6 milli-k. The shim rods are normally outside the reactor core. They are inserted into the reactor core when reactivity is to be reduced even after all the regulating rods are fully inside the core. However, they are not kept for long intervals inside the reactor core. They are withdrawn after sufficient quantity of boron is added to the moderator.

As in the case of the primary and secondary shutdown systems, the reactivity worths of the regulating systems also depend on a variety of parameters defining the reactor core condition – such as what other neutron absorbing materials are already present, where they are inserted and the fuel burnup in the core.

5. Conclusion

Loading thorium in a heavy water power reactor is an important milestone in the Indian nuclear power programme. Although thorium has been irradiated in the Cirrus reactor right from the beginning, this is the first time that thorium oxide fuel bundles are going to be kept in a power reactor for a long time, subjecting the thorium bundles to a fairly high neutron fluence. The experience that will be gained from this exercise will be of immense value in reasserting the confidence that India has already acquired in the various facets of thorium fuel cycle. India is one of the very few countries in the world with large deposits of rich thorium ore but has only limited deposits of uranium of low concentration.

Arriving at a thorium loading configuration that gives satisfactory power flattening without reducing the reactivity worths of any of the different systems of the safety mechanism, either in the initial core or as fuel burnup progresses, is a significant achievement in the neutronics analysis of pressurized heavy water reactors.

Annual General Meeting

The Annual General Meeting of the Canadian Nuclear Society will be held

Wednesday, 2 June 1993 • at 1730 hrs
in the Viger B room of
Le Chateau Champlain hotel • Montreal, Quebec

Reports should be submitted to the President by 15 May 1993.

Although the AGM is being held in conjunction with the 4th International Conference on Simulation Methods in Nuclear Engineering, it is not necessary to register for that conference to attend the AGM which is open to all members.

AECB reviewing CRL waste facility proposal

The Atomic Energy Control Board is presently reviewing an application received from Atomic Energy of Canada Limited (AECL) to construct a new radioactive waste disposal facility at the Chalk River Laboratories in Ontario.

The facility, named "Intrusion Resistant Underground Structure" (IRUS), is intended for the disposal of low-level radioactive waste originating from AECL's nuclear facilities and from various Canadian users of radioactive substances for medical, industrial and research purposes.

The IRUS is different from any of the existing facilities at Chalk River, where the waste is currently considered to be in storage with the intention to retrieve it. In the case of the IRUS, there will be no intention to retrieve the waste, although this will still be technically possible.

AECL's application initiated a comprehensive review of the project by the Control Board as part of its formal licensing process, to ensure the disposal facility can meet AECB requirements with respect to health, safety, security and the environment. As is normal practice during this process, the review is being conducted in consultation with other federal and provincial regulatory agencies invited by the Control Board to assist within their respective areas of expertise.

The application was accompanied by detailed technical documentation describing the proposed disposal facility and its exact location within Chalk River Laboratories site. AECL must also provide details of the public information program required as part of the project.

The proposal is also subject to the Federal Environmental Assessment and Review Process and as part of that procedure, the Control Board will assess the environmental impacts and any related public concerns.

Documents pertaining to this project are available for review in the AECB Office of Public Information in Ottawa.

(from AECB *Reporter*)

Nuclear Fuel Waste Disposal - AECL's Concept and the Importance of Implementation

Colin J. Allan

Colin Allan

Nuclear power now accounts for 17% of the world's electricity supply[1]. As with other methods of generating electricity, environmental concerns are an important issue that must be addressed by the nuclear industry, and one of the principal environmental issues is that of nuclear fuel waste management.

Over the past 14 years Canada has been investigating a Concept for permanently dealing with our nuclear fuel waste. The Concept is based on disposing of the waste in a vault excavated 500 to 1000 metres deep in intrusive igneous rock of the Canadian Shield.

AECL will soon be submitting an Environmental Impact Statement (EIS) on the Concept to a federal environmental assessment review Panel. In accordance with AECL's mandate and in keeping with the detailed requirements of the Panel, AECL has conducted extensive studies on a wide variety of technical and socio-economic issues associated with the Concept. If the Panel recommends acceptance of the Concept, the question will then arise, "When is the appropriate time to proceed with implementation?"

I believe that if the Concept is accepted following the Panel's review, it is important to initiate the process of implementation without delay. In this paper I will outline the reasons underlying this belief but first a brief outline of the history of the program and the environmental review that is now under way.

Colin Allan is AECL Research's Vice-President in charge of the nuclear fuel waste programme.

The Canadian Nuclear Fuel Waste Management Program

Used fuel from Canadian nuclear generating stations is currently safely stored at the sites. Many years of experience have been accumulated with both pool storage and dry storage systems. Supporting R&D indicates that these practices can be safely continued for many decades to come[2,3], but because the used fuel remains hazardous for thousands of years, it is recognized that such storage systems are not a permanent solution.

Accordingly, in 1977 the federal Department of Energy, Mines and Resources commissioned a study led by Professor Kenneth Hare of the University of Toronto to contribute to the formation of a policy for the long-term management of nuclear fuel waste[4]. After considering a wide range of alternatives, the study concluded:

> "Of the various options for disposal of reactor wastes and irradiated fuel, we consider underground disposal in geological formations to be the most promising in Canada. Igneous rocks are preferred ..."

As a step toward a national plan to deal with nuclear wastes, the governments of Canada and Ontario established the Canadian Nuclear Fuel Waste Management Program (CNFWMP) in 1978, to investigate the safety, security, and desirability of a Concept for permanent disposal of the fuel waste in a deep underground repository constructed in intrusive, igneous (i.e., plutonic) rock[5].

In 1981 the two governments reaffirmed their commitment to the program, but announced that the process for selecting a disposal site would not be undertaken until the Concept had been reviewed and accepted[6]. Thus, to date, the R&D program and Concept development have been carried out on a generic basis rather than a specific project basis.

Participants in the R&D program have included AECL, which is the lead agency for research on disposal; Ontario Hydro, which has advanced the technologies for storage and transportation; Energy, Mines and Resources (EMR) Canada; Environment Canada; scientists at Canadian universities; consultants in the private sector; and the general public and special interest groups through public consultation and information programs. AECL has a continuing program to brief the public on the work, to identify public concerns, and to adjust the program to respond to them. AECL's activities are co-funded by the federal government and Ontario Hydro through the CANDU Owners' Group (COG).

In common with the approach adopted in other countries, the Concept involves isolating the waste from the biosphere by a series of engineered and natural barriers[7]. These barriers include:

- the form of the waste itself,
- the container in which it is sealed,
- the surrounding buffer and backfill material, and,
- the overlying mass of host rock (the geosphere).

There is international consensus that this approach can best achieve the goal of safely managing nuclear fuel waste in the long-term. The biosphere is not a barrier per se, but it is an important part of the overall system with which we are dealing, and which we must understand and is therefore a part of the research program.

The fuel waste, in the form of either used fuel bundles or vitrified high-level waste from reprocessing, would be enclosed in corrosion-resistant containers and emplaced in a vault excavated 500 to 1000 metres deep in plutonic rock of the Canadian Shield. Buffer materials would be packed around the containers to impede groundwater flow and retard movement of materials eventually leached from the containers and the waste. The vault and access shafts and tunnels would be backfilled and sealed. Such a system is intended to be a permanent method of management. There would be no intention to retrieve the waste or handle it further in the future, although retrieval would be possible.

The choice of methods, materials and designs for an actual disposal system will ultimately be made on the basis of performance, taking into account the characteristics of the site actually chosen, availability of materials, cost, and practicality.

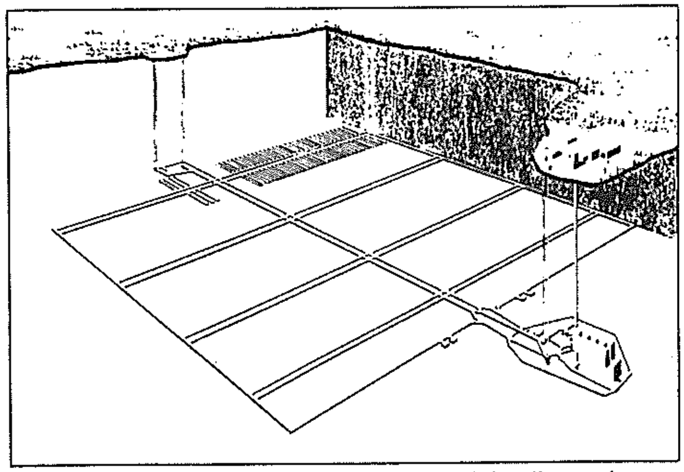
Our approach to Concept development has been to emphasize the performance of the system as a whole and to retain flexibility and robustness in implementation of the Concept.

Over the past fourteen years we have studied the components of this disposal Concept in detail[8]. On the basis of this work we have:

- demonstrated our ability to determine the surface and subsurface characteristics of potential host rock formations;
- demonstrated important aspects of engineering a disposal system and assessing its impact, and we have illustrated this by developing a conceptual design for a used fuel disposal centre;
- demonstrated our ability to assess the long-term performance of such a disposal facility.

In other words, we have developed the tools necessary to design and assess the performance of a disposal facility, tools that we are now ready to apply on a site-specific basis.

While it is not possible to provide complete full-scale demonstrations of all aspects of a disposal facility without actually building one, our case studies of the used fuel disposal facility and the performance assessments of implementing such a facility are based on realistic, albeit hypothetical, facility and site characteristics, using information obtained from extensive laboratory and field research. These studies provide us, and hopefully will provide the review Panel, with confidence that the Concept can be implemented to meet the primary objectives of radioactive waste management, namely: protecting human health, protecting the environment, and minimizing the burden on future generations.



Conceptual design of the vault, showing all the disposal rooms in the first panel and seven rooms in the second panel

The Environmental Review

To test this hypothesis, the Ministry of Energy, Mines and Resources in 1988 referred the Concept for review under the Environmental Assessment and Review Process (EARP)[9]. AECL is the "Proponent" for this review, and will submit an Environmental Impact Statement (EIS) on the Concept to an Environmental Assessment Review Panel.

The Panel will review AECL's Concept and related nuclear fuel waste management issues, including:

- criteria for judging safety and acceptability;
- potential social, economic and environmental effects of waste disposal; and
- the potential impact of recycling and other processes on waste volume.

The Panel is also expected to make recommendations on the approach to be taken to the process for siting such a facility.

A Scientific Review Group appointed by the Panel will conduct a full technical review of the EIS to assist the Panel in judging the technical validity and acceptability of the Concept[10]. All federal departments with a relevant interest are expected to participate in the review. Environment Canada has assembled two teams of experts to review the Concept in detail and assess its ability to protect the environment. Other reviews on specific aspects are expected from the Atomic Energy Control Board; Energy, Mines and Resources, (a task force is being established for this purpose); Transport Canada; Health and Welfare; Fisheries and Oceans; and the Department of National Defence. It appears that the Concept will undergo the most extensive scientific review of any project ever undertaken in Canada. In addition, extensive public hearings will be held. The Panel will then make recommendations on the acceptability of the Concept and for future action.

After a four-year period during which the Panel familiarized themselves with the issues and held hearings to obtain public input, guidelines for the EIS were issued in March of 1992. AECL expects to submit its EIS by the end of 1993. Assuming that there are no major deficiencies, we expect that the public hearings could take place during 1994 and early 1995, and that the Panel could issue its recommendations towards the end of 1995.

If the Panel recommends acceptance, I believe that it is important to take the next steps towards implementation without delay; for several basic reasons:

Environmental Leadership and Reducing the Burden on Future Generations

Since the inception of the nuclear power industry, the industry has shown environmental leadership in managing its radioactive wastes, operating on an essentially closed fuel cycle. The incentive for selecting a permanent disposal Concept for managing long-lived fuel waste derives from two fundamental ethical principles:

- the wastes must be managed in such a way that human health and the environment are protected in the short and long term, and
- as the principal beneficiaries of the energy which gives rise to the waste, our generation should assume, to the extent possible, the burden of managing the waste.

These principles underlie the objectives, criteria and guidelines that the Atomic Energy Control Board has set for judging the safety and acceptability of radioactive waste disposal[11].

From the outset, the Canadian Nuclear Fuel Waste Management Program was founded on the principle that we have an obligation to protect and avoid burdening future generations[12]. Minimizing the burden on future generations means more than simply making financial provisions. It means, to the extent possible, providing the technology to implement disposal and providing it in such a way that future generations may retain flexibility in their decision-making.

Fostering Public Confidence in Nuclear Energy

A second reason for proceeding along the path toward immediate disposal following Concept acceptance is to respond to public concerns associated with the use of nuclear energy. AECL public opinion research shows that two-thirds of the Canadian public say that nuclear power would be more acceptable if a permanent solution could be found for the disposal of nuclear fuel waste. Therefore, progress must continue to be made towards addressing the long-standing public concern about the final disposition of fuel waste.

With the extensive public process that has been followed in developing the Concept, and the vigorous scientific scrutiny to which the Concept will have been subjected, I believe that governmental acceptance followed by immediate steps towards implementation would increase public confidence in the nuclear industry and assist in resolving concerns and controversy regarding nuclear energy.

Forestalling Inaction by Default

My third reason is that, unless there is a clear intention to implement the Concept if it is accepted as a result of the Panel's review, there is a great potential for the review process to fail to lead to a clear commitment to action. Without an impetus towards implementing the disposal Concept, Canada could fail to take any action by default.

Preserving the Knowledge Base

This risk of inaction by default leads me to my last reason for proceeding: to meet our ethical responsibilities to future generations it is important that we preserve the knowledge base that has been generated from the investment that has been made to date. A great deal of technical knowledge has been developed in the course of this program. Tapping this expertise will be essential to successful implementation. While much of the information has been documented, of even greater importance is the ability to interpret the results of tests, measurements and other observations.

Thus for these reasons – our ethical responsibility to future generations; the need to secure public acceptance; the need to forestall inaction by default; and the need to maintain a capability to implement the Concept – I am convinced that, given a positive outcome to the Panel's review, it is important that we take the first steps towards implementing Canada's disposal Concept without delay.

Future Options

There are a number of options for the future in managing Canada's nuclear fuel waste. I believe that they will all include a requirement for geological disposal. The waste substances in used fuel can be disposed either by directly disposing of the used fuel bundles themselves, or by reprocessing them to extract the wastes, incorporating them in a stable matrix, and disposing of this stabilized material.

The question remains as to how we can leave open to future generations the options of fuel reprocessing and recycling, while meeting our ethical responsibility that we not impose an unacceptable burden upon them. In Canada's case, I believe the answer is to be found in the nature of implementation. The process leading to disposal involves many phases. We are now approaching the end of the first phase: Concept development and assessment. If it is judged appropriate to proceed with implementation of the Concept, the next step would likely be to begin site-specific activities.

The process of evaluating specific sites will likely involve ten to fifteen years of work before a commitment would be made to initiate an underground excavation; a further ten to fifteen years of site exploration and characterization would be required before construction could begin: Thus waste would not begin to be placed in a repository before about

2025. By then one would have accumulated many years of site-specific data and a series of increasingly refined evaluations on which to base a decision to begin to emplace waste.

The decision to close and seal the repository would be made taking into account all accumulated evidence and experience gained throughout the siting, characterization and operational phases, a process extending over close to a century.

This process must retain flexibility in implementation and provide opportunities for new technologies and processes to be adopted as they are developed. Throughout the process the option must be retained of stopping the direct disposal of used fuel and substituting the disposal of vitrified waste.

Conclusion

To sum up – the nuclear fuel waste management program was established to develop a sound technical solution for nuclear fuel waste disposal to protect the public and the environment from the harmful effects of wastes associated with nuclear power generation and to relieve future generations of the burden of caring for the waste. The wastes exist now and we have a responsibility in this generation to dispose of them. From our R&D program we believe that we have developed a sufficient level of technical understanding and capability to continue through towards disposal following the environmental review. If the Concept is accepted, we can and should continue our responsible approach and take the next steps towards constructing a disposal facility for Canada's used fuel wastes.

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Upcoming CNS Meetings

April 2, 3 — **Student Conference**
Montreal, Quebec
contact: D. Rozon
Tel. (514) 340-4803

April 21 — **Seminar "Fusion Energy: Technological Challenges and Opportunities for Industry"**
Toronto, Ontario
contact: Shayne Smith
Tel. (416) 673-3788
FAX (416) 673-8007

May 17-19 — **CANDU Reactor Safety Course**
Toronto, Ontario
contact: Joel Almon
Tel. (416) 506-6889
FAX (416) 506-4240

June 2-4 — **4th International Conference on Simulation Methods in Nuclear Engineering**
Montreal, Quebec
contact: A. F. Oliva
Tel. (416) 592-7670

June 2 — **CNS Annual General Meeting**
Montreal, Quebec
contact: Wm. Midvidy
Tel. (416) 592-5543
Ben Rouben
Tel. (416) 823-9040
FAX (416) 823-8006

September 13-14 — **International Conference on Expanded and Rolled Joint Technology**
Toronto, Ontario
contact: Gary Kharshafdjian
Tel. (416) 823-9040 Ext. 2102
FAX (416) 823-8006

Briefing on Deep Geological Nuclear Waste Disposal Concept

Representatives of several federal and Ontario departments and agencies gathered in Ottawa recently for a "status briefing" on the deep geological disposal concept for nuclear fuel waste being pursued by Atomic Energy of Canada Limited and on the review of that concept being conducted by the Federal Environmental Assessment and Review Office (FEARO). The briefing took place January 25 and was repeated January 26, with about 30 attendees each day.

AECL is currently working on the Environmental Impact Statement (EIS) required for the FEARO review. FEARO issued the final guidelines for the EIS in March 1992. Colin Allan, the AECL Research vice-president responsible for the program, stated that AECL expected to submit the EIS by the end of 1993.

On that basis, Guy Riverin, executive secretary of the Environmental Assessment Panel established by FEARO to review the deep geologic disposal concept, predicted that public hearings might be held as early as the fall of 1994 and the Panel report submitted by the summer of 1995. However, if the Panel judges the submitted EIS to be inadequate that timetable could slip by 6 months to a year, i.e., the panel report may not be submitted until the end of 1995 or well into 1996.

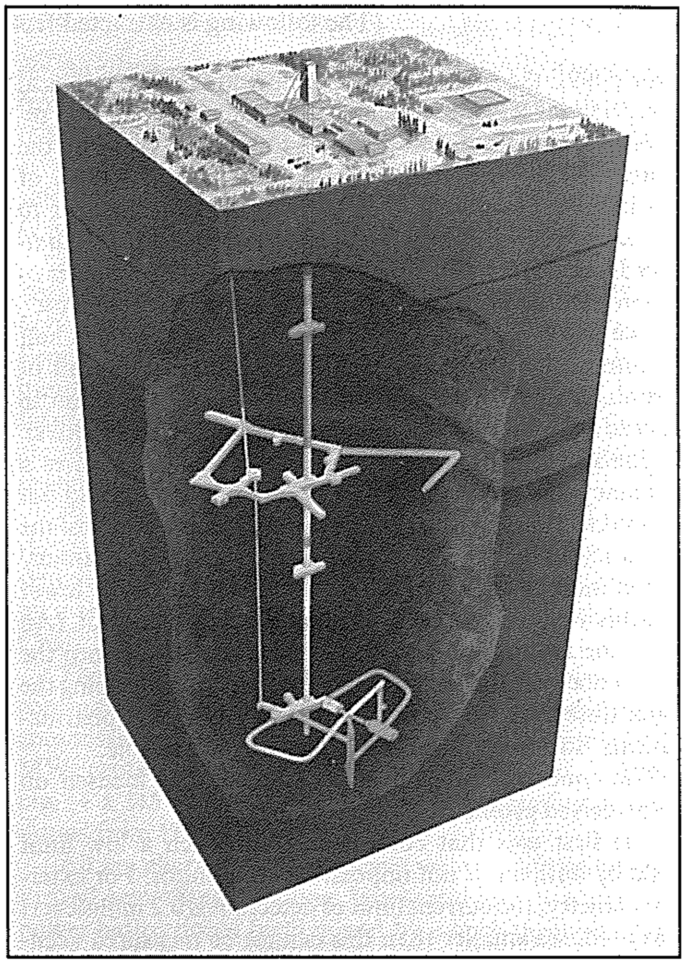
The long-term nature of the program was emphasized by Bob Morrison, director-general of the electricity branch of the Department of Energy, Mines and Resources, who served as chairman of the meeting. "There is no technical urgency for disposal", Morrison said, "however, there is a need to identify an option". He noted that the earliest that any high-level waste would be put into an actual depository would be 2025 and closure would not be for at least 50 years afterwards. Jokingly he said he expected to be at the closure ceremony!

In his opening address Dr. Morrison referred to the Hare report of 1977 which set out general factors and objectives. The following year AECL and Ontario Hydro (OH) agreed to a joint program with AECL to examine long-term disposal of high-level waste and OH to concentrate on low and mid-level wastes and transportation. In 1981 this arrangement was re-confirmed, leading to major programs totally about $45 million per year. AECL has concentrated on proving out the **concept** of deep geologic disposal in plutonic rocks of the Canadian shield.

In 1988 the Minister of Energy, Mines and Resources referred the **concept** to the Minister of the Environment for review by FEARO. In turn FEARO established an Environmental Assessment Panel in 1989. The review of a **concept** as distinct from an actual project was a new challenge for FEARO. To assist in the review the Panel created a Scientific Review Group in 1991 to conduct a critical analysis of the scientific and technical aspects of the concept.

The Panel held a series of public "scoping sessions" in the fall of 1990 prior to issuing draft guidelines for an Environmental Impact Statement in June 1991. After reviewing many comments the Panel issued the final EIS Guidelines in March 1992.

The Panel's mandate includes topics which are outside AECL's role. These "broader issues" include criteria for evaluating the safety and acceptability of the concept, other approaches to high-level nuclear waste management, criteria for siting a facility, and the social, economic and environmental implications.



This drawing illustrates the Underground Research Laboratory in Manitoba, a major feature of AECL's work on the concept for Deep Geologic Disposal of nuclear fuel waste

Regulatory criteria have been expressed by the Atomic Energy Control Board in regulatory policy documents issued in 1985 and 1987. Ken Bragg, head of nuclear fuel waste and special assessments at the AECB, stated that there had been no change in these criteria except for the radiation conversion factor (deaths per Sievert of dose) which has been increased by a factor of 5 in keeping with recent recommendations of the International Commission on Radiological Protection (ICRP). (The AECB has announced that it intends to revise radiation dose limits to reflect these ICRP recommendations.)

When asked what FEARO would do if the Panel concluded that the AECB criteria were not appropriate or adequate Riverin said FEARO could make recommendations to the government while acknowledging that FEARO had no jurisdiction over the AECB which is established as an independent regulatory agency.

Many of the attendees expressed their appreciation for the updating, even if their departments or agencies were unlikely to be involved directly. There appeared to be general agreement with Morrison's view that the work must proceed even though there is no technical urgency.

AECB reviews dose limits for pregnant ARWs

(The following is extracted from an article in the AECB *Reporter*).

In early 1991, the International Commission on Radiological Protection (ICRP) published recommendations for the reduction of radiation dose limits. This was followed by the release by the Atomic Energy Control Board (AECB) of Consultative Document C-122, *Proposed Amendments to the Atomic Energy Control Regulations for Reduced Radiation Dose Limits Based on the 1991 Recommendations of the International Commission on Radiological Protection.*

The AECB received a number of responses. Almost half the comments came from medical institutions, and all of these expressed concerns about the proposed reduction in the dose limit for pregnant atomic radiation workers (ARWs).

The ICRP recommended that once a worker declares a pregnancy, the surface of the woman's abdomen should not be subjected to more than 2 mSv during the remainder of the pregnancy. In the case of internal doses, a limit of 0.05 annual limit of intake (ALI) implies that a level considerably lower than this would have to be detectable for dose control. (An ALI is the amount of radioactive substance taken into the body in one year that will result in the individual reaching the annual dose limit.) For several commonly used radiopharmaceuticals, no accepted method of bioassay is available.

The concerns raised by the commentaries focused on two perceived problems.

The first was that compliance with such a low limit would be difficult, if not impossible, to monitor. For external dosimetry, the current limit of detection is 0.2 millisievert (mSv) – doses smaller than this cannot be measured accurately. If a pregnancy is declared one month after conception, up to 18 two-week periods would remain before the birth of the child. Therefore, if the two-week schedule for dosimeters is maintained for pregnant ARWs for dose control, about a 3.6 mSv dose would be "missed," i.e., 18 x 0.2 mSv or about 3.6 mSv would go unrecorded. This number is greater than the proposed limit of 2 mSv, and some additional dosimetry would therefore be required.

The second area of concern was about employment. With the difficulty of either meeting the proposed limit or demonstrating compliance with it, employers would transfer ARWs to non-radiation work if they became pregnant. However, some employers, such as hospitals with small nuclear medicine departments, would be unable to transfer or reassign workers to avoid radiation exposure and would be forced to lay them off.

This scenario would present hardships to employees. Only the Province of Quebec has a system in place to maintain such workers' income. In addition, the hospital would have to find a replacement and qualified people may be hard to find. In the long term, it was feared that employers would be reluctant to hire women for ARW positions.

Following a preliminary meeting in February 1992, it was decided to hold a series of meetings across the country with female radiation workers.

Meetings targeting nuclear medicine technologists along with other medical workers were held in seven major cities during October and November 1992. In all, well over 300 concerned individuals attended. An additional meeting was held in December at the Key Lake uranium mine. Some of the gatherings were attended by female workers from power utilities and various Canadian research establishments.

The meetings included a presentation by Dr. David Myers, a consultant to the AECB, on the risks to the foetus and the basis of the ICRP recommendations. A summary of the written comments on C-122 was also presented. This was followed by the opportunity for presentations from representatives of professional associations, employers and unions. Attendees then broke into small groups and prepared suggestions for the formulation of a regulation. A summary of their main comments follows.

1. Dosimetry must be improved. This is especially true of internal dosimetry which at present is not adequate to indicate compliance with the proposed limit.
2. In view of the problems with bioassay, contamination surveys should be accepted instead of estimates of intake based on bioassay.
3. More educational material, explaining the risks, is needed for radiation workers.
4. The AECB should conduct a study on Canadian medical radiation workers to examine their doses and the medical history of their children.
5. The AECB should prepare a compendium of low-cost dose devices and practices used by hospitals and laboratories, and make the information available to all.
6. The social and economic impact of the C-122 proposal should be determined by the AECB.
7. The philosophy of setting the dose limit for the foetus the same as the public limit is acceptable, but the ICRP recommendation on the public dose limit is too low.
8. The risks do not justify such a drastic change in the limit (some groups felt there was justification in having no change).
9. The strongest suggestions for the actual limit were for a compromise between 2 and 10 mSv, but several groups saw no reason to change the current limit of 10 mSv.
10. A few groups stated that the mandatory declaration of pregnancy required by the *Atomic Energy Control Regulations* was an invasion of privacy.

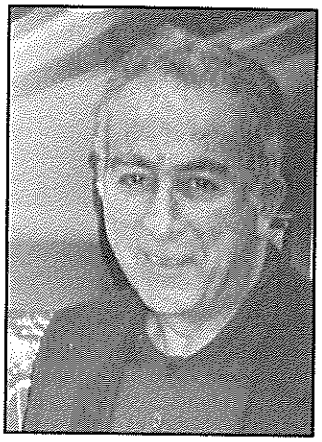
It was apparent that nearly all felt that the ICRP recommendation was too restrictive and was not justified by the risks. If implemented, it would result in lay-offs and eventual reluctance of employers to hire women in the nuclear medicine field. Participants were also of the opinion that demonstrating compliance would be impossible and recommended two options: either a compromise limit of 4 mSv, or remaining with the current limit of 10 mSv over the duration of the pregnancy.

AECB staff are developing a new proposal on the dose limit for pregnant ARWs which will be included in the revised C-122 proposals to be published in Part I of the *Canada Gazette*. At that time further comments will be invited.

Reflections on the Canadian Program

Ara Mooradian*

Ed. Note: *This paper is taken by Dr. Mooradian's comments to a special anecdotal session at the ANS conference celebrating the 50th anniversary of the first nuclear reactor, held in Chicago, November 1992.*



Ara Mooradian

Our story originates in France. The first patents recognizing the need to moderate fission neutrons were issued in Paris to the team of Joliot, Halban, Kowarski and Perrin back in May 1939. Recognizing the unique attributes of heavy water as a moderator, the French cornered the world supply (185 kg), and moved it from Norway to France (March 9, 1940) just a few weeks before the invasion of Norway. Shortly thereafter (June 17, 1940) Halban and Kowarski fled to the Cavendish Laboratories with their heavy water to escape the German occupation and to continue their studies.

At the end of December 1940, Cockcroft wrote from Cambridge, "Halban has obtained strong evidence that D_2O, U slow reactor will go . . ."

By 1942, the UK was itself vulnerable, and the government proposed that the heavy water group led by Halban be moved. Halban preferred the US. However, by this time, the US role was well launched on its own program and offered Halban a berth but not a leadership role for himself and his team, which was fortunate for Canada, the second choice.

While Canada was able to contribute a group of first rate scientists, there is little doubt that the key factors in encouraging Canadian participation were its friendly proximity to the US and its rich uranium deposits at a time when the element was thought to be scarce.

The Canadian program was effectively born on August 17, 1942 when C.J. MacKenzie (then president of the National Research Council of Canada) sold the UK proposition to C.D. Howe, then Canada's wartime "minister of everything." Shortly thereafter the heavy water took up temporary headquarters in Montreal.

There followed a frustrating period until effective cooperation with the US was launched at the Quebec summit (August 1943) by Roosevelt and Churchill.

In April 1944 Cockcroft arrived in Montreal to take over the Anglo-Canadian team.

By July of that year, ZEEP (a low power D_2O lattice facility) was committed under Kowarski as project leader to set the nuclear parameters of NRX and later NRU. By September, the plant layout for Chalk River Nuclear Laboratories (CRNL) was approved and the NRX design was well underway.

On September 5, 1945 ZEEP went critical (the first outside the US) almost precisely as predicted by J. Stewart and G.M. Volkoff.

At the end of the war, the UK recalled Cockcroft to head the UK program and W.B. Lewis (at age 38) was appointed to replace Cockcroft at Chalk River. He arrived September 18, 1946 and later told me that Cockcroft handed him three sheets of foolscap with the essentials of how in future the large store of energy in uranium and thorium could be harnessed; all the instruction he needed to set in motion Canada's greatest scientific mission.

Power reactor development was the principal focus of the program the moment the war was over. The first formal step took place in 1954 when a feasibility study was launched by a team of engineers from the utilities, industry and the Chalk River laboratories.

There followed an incredible cascade of overlapping commitment. First, NPD (a 20 MWe demonstration) plant commissioned in 1962, followed by Douglas Point, (a 200 MWe prototype) commissioned in 1967 followed by Pickering, (4 x 515 MWe), our first commercial station commissioned from 1971-73.

All are characterized by heavy water moderation, pressurized heavy water cooling, horizontal pressure tubes, on-power bidirectional fuelling and by a once-through natural uranium fuel cycle. These essential elements continue to characterize all CANDU reactors committed since then.

Now let's examine how it was done.

Essential Components of Success:

(A) Just-In-Time Leadership:

From its inception the program was characterized by timely and strong leadership. It's hard to identify more appropriate men than C.D. Howe and C.J. MacKenzie to appreciate the significance of the atomic era. C.D. Howe, as head of defence production had almost single-handedly launched Canada's industrial era. MacKenzie, his trusted technical advisor, was leader of Canada's scientific effort throughout World War II and had done much to put science to work in the national interest. Between them they had the vision to appreciate the nuclear opportunity and the confidence to seize the moment.

Although we did not have Sir John Cockcroft for long (April 1944 to September 1946), we had him at a critical time, first as scientific director of the Montreal Labs and later the Chalk River laboratories. He organized an excellent scientific team and laid the foundation for the Canadian program. He had the reputation needed to commit the low power ZEEP and NRX, Canada's 40 MWt research flagship into the nuclear era. More important, he persuaded W.B. Lewis to succeed him as scientific director.

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Dr. Lewis provided the program's intellectual driving force. The breadth of his interests and contributions spanned the entire spectrum from the fundamentals of all of the physical disciplines to their application. We were never without a clear vision of where we were, where we were going and why our mission was sustainable. All who touched him were left with a taste for fundamentals, for significance and for excellence. He is our most decorated nuclear scientist and recognized both in Canada and abroad as father of the CANDU concept.

Less well recognized internationally but crucially important to the Canadian program was J.L. Gray who was appointed general manager of AECL in 1952 and subsequently president from 1958 to 1974, the period over which CANDU was transformed from a concept to a commercial reality. It was Gray who earned the confidence of governments, utilities and of the commercial community both at home and abroad to the extent needed to successfully manage and finance the program. When you remember that it took 20 years before we registered the first clear commercial success in power generation, it will give you some indication of the qualities of this man.

Together Lewis and Gray struck the right balance between scientific drive and practicality. For example, while Lewis recognized the importance of establishing the feasibility of high performance fuel cycles, Gray recognized the market significance of the simple once-through natural uranium fuel cycle. The result was a strategy of evolutionary development now proven appropriate to the time and resources.

(B) Cohesion

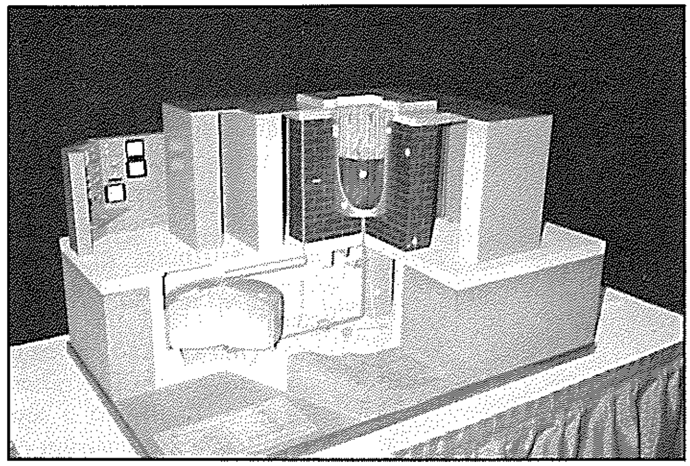
Possibly the most important single attribute of the Canadian program is the one most difficult to identify, i.e., cohesion. Long before we heard about "team Japan" we had a "team Canada" in the nuclear power program. Its importance was recognized from the earliest moments. For example, when the program was brought under the umbrella of a crown corporation in 1952, the Board of Directors was composed of the leaders of Canada's major electrical utilities, and of the commercial and academic sector. A strong utility representation was maintained throughout the conceptual studies and subsequent engineering of the first plants. The operators and suppliers were all brought into the picture at a very early stage, and participated in the development of the concept. It is therefore no surprise that the program enjoyed a lobby of support which was hard to ignore. Perhaps our smaller size had something to do with avoiding the fragmentation which proved worrisome to the larger nuclear nations. Whatever the reason, cohesion proved our strongest asset.

(C) International Cooperation

International cooperation was extremely important both from a political and technical point of view. For the politicians it was comforting to know that the Canadian program had the benefit of the best international contacts. Since Canada had no pretensions of becoming a nuclear weapons state, there was little impediment to the exchange of information.

Our excellent test facilities, NRX and NRU were attractive to our offshore colleagues and did much to encourage collaboration.

As a tangible indication of the cooperation that characterized the 50s and 60s, I recall an occasion when Admiral Rickover paid us a visit in August 1956. While touring my Engineering Development Branch, he made what appeared to be an off-the-cuff offer of help, if needed, to get NRU up



Model of "ZEEP"

and running. One of the important problems that we had in NRU (which was on-power fuelled) was a drive nut for the fuel shroud needed to retain the integrity of coolant flow while fuel was being extracted. This nut operated on a 316 stainless steel screw, 10 feet long, lubricated with clean warm heavy water. The only material that looked as though it could do the job was oxidized zirconium metal of which Canada had but a minor precious supply at the time.

I called the Admiral's office, introducing myself and to my surprise was immediately put through. The conversation lasted all of one minute. I told him that we badly needed 300 pieces of zirconium of certain minimum dimensions and that we needed them in three weeks. Incredibly, these came to us from all over the United States on time, on dimension, and without a bill. Small wonder we called these "the good old days." Incidentally, the zirconium drive nuts are still in-service today – over 30 years later.

(D) Natural Uranium

A hidden advantage we had in Canada was the *absence* of a uranium enrichment capability. This drove us to the natural uranium system and a discipline that had a profound influence on the reactor development program. It established a culture of neutron economy that has prevailed to this day. Even more important, it resulted in a very sharply focused program. We flirted with uranium metal as a fuel but not for long. It was barely tolerable in the warm water environments of NRX and NRU but clearly not acceptable for power reactor service.

We also examined low nickel aluminum alloys for cladding and uranium silicide fuels. The possibilities were so few that it was not hard to recognize the excellent prospects for UO_2 fuel and zirconium alloys for cladding and pressure tubes when they were brought to our attention by the US program.

It was not all one way. Our program has made notable contributions to the US as well. I recount but one to illustrate.

In the late 50s and early 60s, American designers were in the process of selecting cladding materials for enriched reactors. The candidates were stainless steel and Zircaloy. At a critical period, the Vallecitos group reported a test which indicated that Zircaloy clad fuel fell apart in a matter of hours when operated in a defected condition. These results were in direct conflict with our experiments, which indicated that (UO_2) fuel with defected Zircaloy cladding could live without catastrophic damage under power reactor conditions for weeks, not hours. We judged the consequences of the Vallecitos experiments could be far reaching. If zirconium prices were to come down to a level required for economic fuel, it was important to establish a large, international market for the material. Unchallenged, the Vallecitos results could turn US workers away from zirconium and Canadian fuel producers would have to pay much higher prices for zirconium products. By some detective work we were able to determine that the Vallecitos fuel had likely been contaminated with fluorine. Since it was known that fluorine destroyed the corrosion resistance of Zircaloy, we reasoned that the combination of steam and fluorine could result in rapid deterioration of the cladding. What was needed was a rapid experimental confirmation which could be published in time to restore confidence in Zircaloy. In a matter of three months, tests were set up in an NRX loop in which two fuel elements were irradiated together under power reactor conditions. They were identical in all respects save that one was contaminated with fluorine. The results came quickly. Within hours, the fluorine contaminated element suffered severe damage while the uncontaminated element reconfirmed our earlier results. A repetition gave identical results. These findings were quickly published and, we believe, did much to ensure that Zircaloy remained the cladding of choice.

(E) Heavy Water Cooling

The use of pressurized heavy water as coolant proved to be an extremely important discipline on the entire development program. Because it is expensive and obviously so, the program had to pay particular attention to its containment. This forced us to examine the entire design to remove and control as many points of leakage as possible, to concentrate on the corrosion and chemistry control of large surface areas such as steam generators, heat exchangers and pipes, to invent non-leaking valves and to develop the science underlying pump seal design. The results have been nothing short of dramatic. If a less valuable coolant had been chosen we would not have been forced into the technology of coolant system integrity at such an early stage in our program. As matters have evolved, it appears that the integrity of the primary coolant system is an important consideration in any practical power reactor design, whatever the coolant. The excellent boiler performance and control of coolant chemistry which characterizes CANDU systems is directly attributable to the discipline imposed by the value of heavy water.

Diversions:

It would be erroneous to leave you with the impression that the Canadian program was so finely focused, that we suffered no significant diversions.

(A) Fuel Recycle

In the early stages of the program, like others, we were sensitive to the possible shortage of affordable uranium and hence, the need to demonstrate improved utilization of natural uranium by plutonium recycle. We had already developed fuel processing to extract Pu from NRX fuel for the military program so it was a natural extension to examine the feasibility of plutonium recycle. Also, both Cockcroft and Lewis foresaw the possibility of a thermal breeder by combining the thorium-U^{233} cycle with a tightly engineered heavy water reactor. It made a lot of sense to explore the flexibility of invoking progressively more efficient fuel cycles up to and including self-sustaining cycles without having to invoke a convulsive change in reactor technology.

While it was valuable to establish the feasibility of the CANDU recycle options, in retrospect we probably had a more active experimental program than now seems appropriate. Certainly in today's environment there is no commercial contest with the simple and inexpensive once-through uranium cycle.

(B) Alternative CANDU Concepts

Other significant diversions occurred throughout the late 50s and 60s. Having launched the reference *P*ressurized *H*eavy *W*ater cooled (CANDU-PHW) line, we set up a Power Reactor Development Program Evaluation Committee in 1962 to examine the relative merits of alternative coolants. Two candidates emerged both of which we took to an advanced state of development.

CANDU-OCR (Organic Cooled Reactor)

One of these was the so-called CANDU-OCR (for *O*rganic *C*ooled *R*eactor). We were not alone in our interest in organic coolants. Euratom had its ORGEL project; the US, PIQUA; and the Soviets ARBUS.

Canadian interest dates back to 1958 at Canadian General Electric. Subsequently, we built several loops, both in and out pile and mounted a significant program which ultimately led to the commissioning in 1965 of WR-1, a D_2O moderated, organic cooled, pressure tube experimental reactor (initially 40 MWt and subsequently stretched to 60 MWt). It was designed and built by Canadian General Electric and was the centrepiece of the new Whiteshell Nuclear Research Establishment at Pinawa, Manitoba. Over the period of its operation from 1965 onward, it proved to be a remarkably tolerant system. The coolant we chose was a partially hydrogenated terphenyl called HB-40, which was liquid at room temperature.

It is possible to use zirconium alloys in this system as both cladding material and pressure tubes. Indeed we operated for 20 years at coolant temperatures in the range 350°C-400°C using these materials.

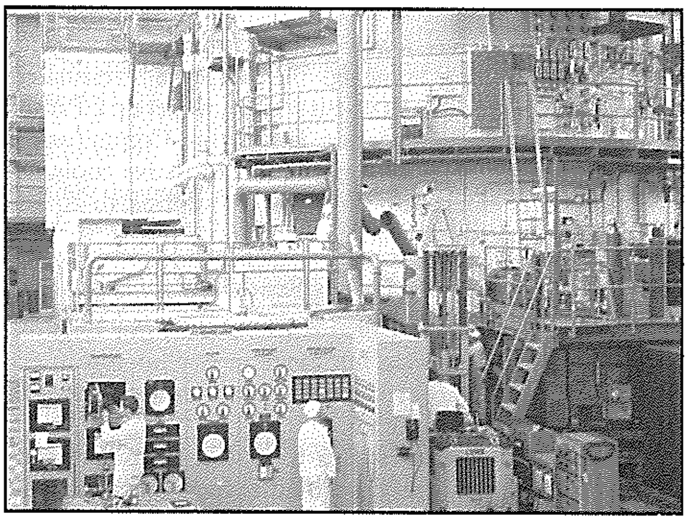
Remarkably, the system displayed virtually no activity transport. After years of operation, we were able to maintain the primary circuit with contact maintenance.

Alas, timing is everything and despite its exceptional promise, the organic cooled reactor was simply too late to overtake the water cooled systems. WR-1 survived as an excellent test reactor and gave many years of useful service following the decision to shelve the CANDU-OCR in 1973.

CANDU-BLW (*Boiling* Light *Water* Cooling)

What could be more attractive in concept than the marriage of the neutron economy of heavy water moderation with the practicality of light water cooling? We went even further down the BLW road than we did with the OCR. We actually built a 250 MWe prototype (G-1) plant at the Gentilly site in Quebec. Commissioned in 1971, the plant worked quite well. However, units larger than this (of the capacity now required) would need some enrichment to give sufficient control stability. By this time, the benefit of the simple natural uranium fuel cycle was firmly established as a compelling attribute of the first generation plants and no further commitments were made in Canada to the BLW concept.

While both the OCR and BLW were certainly diversions, they served the important function of keeping intact a coherent and pertinent R&D capability later needed to support the commercial line of development.



A view of the NRX reactor, circa the 1960's. Photo provided by Public Affairs Office, Chalk River Laboratories, AECL Research.

(C) The Intense Neutron Generator (ING)

The Canadian story is incomplete without some comment on a very imaginative proposal which was developed during the early 60s. Dr. Lewis was committed to a dynamic basic research capability as an imperative of a productive laboratory, and equally committed to the related need for world-class facilities to attract and stimulate the best minds. Consistent with this philosophy Chalk River was not allowed to relax its claim as a world class neutron flux generator. When NRX was commissioned in 1947 it was recognized as the world's leading test reactor (first operated up to 30 MWt and subsequently 40 MWt). It was barely commissioned before thought was given to the next advance which resulted in the 200 MW NRU (startup in 1958) which offered a large enough volume of neutron flux, an order of magnitude higher than NRX, high enough to execute experiments under full power reactor conditions. Consistent with this philosophy, attention in the early 60s began to focus on the next major step. A group was assembled to examine all alternatives including fission and fast reactors as high flux generators. What emerged in 1964 as the preferred choice was the Intense Neutron Generator (ING), a concept based on the spallation reaction.

The proposal consisted of generating a 65 MW beam of 1 GeV protons in a mile-long linear accelerator and firing this beam into a liquid bismuth target. This would cause neutrons (about 20/collision) to boil off the target materials and simultaneously generate enough power to make the beam essentially self-sustaining while producing U^{233} from a surrounding fertile Th blanket. The thermal flux would be in the order of 10^{16} neutrons per square centimetre per second. A project of this magnitude inevitably attracted a nationwide technical debate. The timing was not auspicious. University science budgets were threatened and insufficient support was marshalled before the question was put. In September, 1968, AECL was instructed to terminate the ING project.

Conclusions

Throughout the last 40 years, the consistent Canadian strategy has been to develop to commercial viability a neutron conserving heavy water system on a once-through natural uranium cycle and to subsequently evolve more efficient fuel cycles for the same reactor system when needed. History has proven this to be a sensible strategy which has avoided the trap of premature industrialization of fuel recycle while retaining confidence in long term fuel supply.

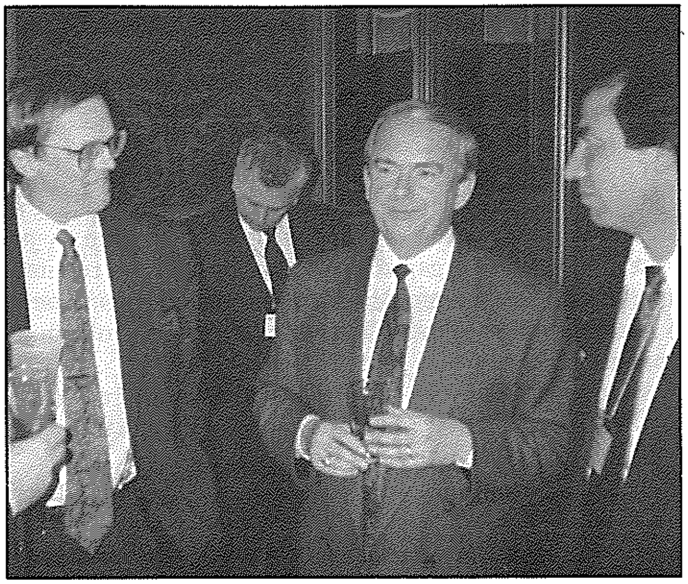
The first two decades were a wonderful time. The pioneers were individuals, their work was apparent, the public was friendly, the regulators were knowledgeable and focused on "real" safety, the few accountants and lawyers in the decision chains were looking for ways to support programs, and governments were enthusiastic and supportive. Very little of the creative resources of the period were wasted on accountability for diversions or mistakes. Why, we actually had premiers of Ontario elected on platforms which openly endorsed nuclear power. We even had a Royal visit at Chalk River on July 28, 1964.

It was Lew Kowarski who best captured the essence of the spirit which has kept the Canadian program a "GO" proposition over this past five decades. During a 1971 visit to Chalk River, in response to a question regarding the prospects for heavy water reactors, he answered, "Physics is immutable, business will adjust."

CNA/CNS Winter Meeting

Ottawa was again the venue for the annual winter meeting of the Canadian Nuclear Association (CNA) which was held February 9. This year the meeting was billed as a seminar, with the theme "Energy Politics", and was co-sponsored by the Canadian Nuclear Society (CNS).

As has become the pattern for the past few years, the evening of February 8 saw a reception in the west block of the parliament buildings with a number of members of parliament attending.

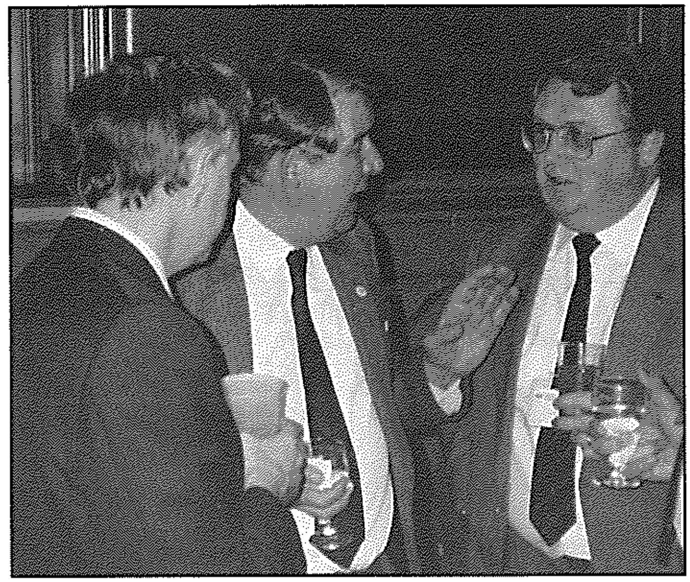


Rudy Sligl, Tom Drolet and Bill Midvidy share a moment during the CNA/CNS Winter Meeting in Ottawa.

The seminar included: a talk by Ken Talbot, Manager of the Bruce "A" plant; Tom Drolet speaking on Ontario Hydro's international activities; Gerald Grandey, vice president of CAMECO, reviewing the uranium scene; John Marchildon of the Ontario Allied Construction Trades Council giving a union perspective on Ontario Hydro's nuclear program; Roxanne Summers, of the CNA, commenting on the CNA's public information programs; and Dave Sinden of the Atomic Energy Control Board defending the AECB's cost recovery policy.

Dr. Angus Reid, of public polling fame, intrigued his luncheon audience with his comments on the changing political and public perceptions. He noted a concept of "energy correctness" paralleling that of "political correctness", which includes thoughts such as: "small is beautiful" (e.g. cogeneration); "don't trust the big guys in suits"; "experts are wrong". Observing that we are in a political grid-lock he commented that there is little political concern about the supply of energy. He predicted that new forces will soon come into force and we need to maintain our capability for the nuclear option.

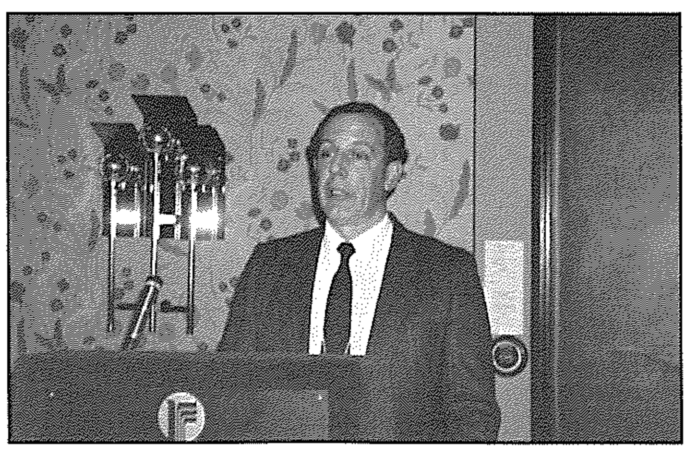
Grandey noted that world uranium prices remain low, despite no new production in the western world, largely because two producers in the former USSR are now offering uranium on the world market. Nevertheless he predicted that price recovery was inevitable since (western world) consumption far exceeds production (123 million lbs U3O8 per year vs. 61). Canada is now the leading producer in the western world with 38 % of the total.



NB Power's Roger Mackenzie makes a point to Bob Keating, AECL, VP Atlantic, while EMR's Bob Morrison (back to camera) looks on, at the CNA/CNS Winter Meeting in Ottawa, 9 February 1993.

Sinden stated that the federal government first mandated the cost recovery policy in 1984 and applied it to many programs, not just the AECB's. The AECB held extensive consultations between 1987 and 1989 before introducing its program in 1990. Fees are based on historical (previous year) costs and are reviewed by Treasury Board. The AECB's staff expansion (about 50% over the past three years) was a case of "unfortunate timing" according to Sinden who insisted that the AECB does not have "carte blanche" to expand at will. He said that while the AECB is interested in further dialogue with the industry it cannot be perceived as being controlled by the industry. When asked about accountability he stated that the AECB is audited by the Auditor General.

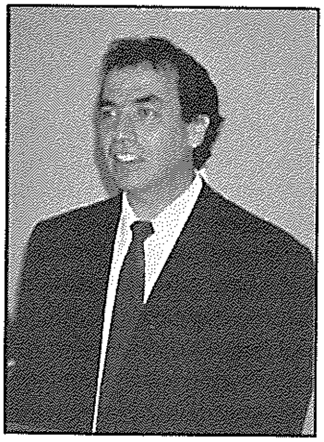
There were 114 registrants for the seminar but, despite the co-sponsorship by the CNS, very few CNS members present.



David Sinden explains the AECB's cost recovery program at the CNA/CNS Winter Meeting, 9 February 1993.

The CNS in a 'lean and mean' industry

Ed. Note: *Following is the text of CNS President Bill Midvidy's address to the CNA/CNS Winter Seminar held in Ottawa, February 9, 1993.*



Bill Midvidy

The main point of my presentation is that the CNS can help high-tech organizations in the nuclear industry be lean and mean.

First Some Background

The Canadian Nuclear Society was founded in 1979 to provide a forum for individuals interested in the exchange of expertise, knowledge and information on nuclear science, engineering and technology. In addition to organizing conferences and seminars, the Society publishes a quarterly bulletin which includes news items, announcements, reports, editorials, and technical papers.

Regular conferences include the CNS/CNA Annual Conference, the Annual Student Conference, and the annual CNS Simulation Symposium on Reactor Dynamics and Plant Control. Several topical conferences and short courses are also sponsored by the CNS. We frequently co-sponsor conferences organized by the Nuclear Societies of other countries.

To best meet local interests, the CNS has created ten regional branches in five provinces, from Saskatchewan to New Brunswick. Each has its own executive committee, budget and program of activities which may include invited speakers, tours and social functions. In addition, the CNS has four technical divisions which organize conferences on specific topics.

Major Activities in 1992

In 1992, excluding the annual conference in Saint John, the CNS sponsored or co-sponsored five conferences or symposia. In March the annual Student Conference was held at McMaster University in Hamilton. The conference attracted 55 attendees, of which 43 were students, for the two-day meeting. Six technical sessions with a total of 33 papers (26 graduate and seven undergraduate) were presented. The strong *student* involvement in most of our events is by design, not accident.

In May, the meeting on Radiation Safety in Uranium Mining was held in Saskatoon. It was well attended with 117 delegates from *9 countries*. The strong presence of offshore delegates is also by design. Good quality presentations were the norm covering uranium mining epidemiology, radiation protection procedures and lung dosimetry models. The Annual Conference in Saint John was a technical success with about 106 papers in 16 sessions offered to attendees. The CNS Simulation Symposium was held at the Royal Military College, Kingston, in August. 60 participants were attracted to this annual event.

The latter part of the year saw two very successful conferences. In October, the Third International Conference in CANDU fuel was held in Pembroke. The event attracted 91 delegates from *6 countries* with over 50 papers presented. The success of this conference was reflected in the expressed desire of the attendees to hold a fourth conference in two years' time.

The best attended conference of the year was the Second International Conference on CANDU Maintenance, held in Toronto. It attracted over 300 delegates for the 2 day event in late November. The conference content and format elicited favourable comment from the attendees and it was obvious the conference needs to be held every 2 to 3 years. It is 5 years since the first conference.

One course, the Regional Overpower Trip Course, was held in Mississauga in March. We, and in particular the Nuclear Science and Engineering Division, have been trying for several years to organize other courses but have run into difficulties. The main problem is finding qualified *volunteers* to lecture at these events. I'll be discussing this problem in more detail shortly.

Preparations for the INC93 Conference are proceeding well. The CNS is heavily involved in arranging the technical and educational programs.

1992 has been an active year in most of the ten local Branches of CNS. These are now spread across Canada from Saskatchewan and Manitoba to Quebec and New Brunswick, with six branches in Ontario. The general CNS thrust to reach out and interact with the public is being led by a number of these Branches, with greater involvement in educational activities and public policy forums. One important activity in several of these Branches was to organize and sponsor activities with local schools which are funded by the CNA/CNS Educational Fund.

Particular highlights from 1992 include the excellent program of activities organized *again* this year by the Toronto branch in collaboration with the University of Toronto's Centre for Nuclear Engineering. Another highlight would be the resurgence of the Chalk River Branch under the very active executive led by Aslam Lone. The branch not only established a very successful program of guest speakers, but have initiated joint programs with Algonquin College and other local Societies. They have also established a "Science Writers Group" on nuclear topics. This group assisted with the preparation of the CNS submission to the Ontario Demand/Supply hearings.

The Saskatchewan Branch focused on public education, with four high profile and well attended presentations. The branch was a formal participant in the Environmental Impact study for the proposed Rabbit Lake Mine Development, and has made presentations and briefs on behalf of the nuclear industry to both Municipal and Provincial Government officials, as well as participating in several public discussions and debates. This intense public activity by members of the Saskatchewan Branch helped to create the atmosphere which permitted the Saskatchewan Government to reopen negotiations with the Federal Government and AECL regarding an expansion of the nuclear industry in Saskatchewan.

The Future

During the coming year, we will work to help the other Branches approach this level of activity.

In addition, the CNS continued to present the views of its members to enquiries and commissions, both national and provincial, by submitting briefs and arranging appearances by representatives.

I firmly believe that the CNS should be useful to almost any company in Canada's nuclear industry, particularly lean and mean high-tech companies. The reasons/benefits are as follows:

- the CNS provides an inexpensive forum for people or organizations interested in nuclear science, engineering and technology
- the CNS organizes conferences, seminars and courses which are a relatively inexpensive way of providing training, professional development

More details on these generalizations. CNS conferences provide:

- recognition and credibility of our work
- an opportunity to maintain and build expertise
- an opportunity to learn from our colleagues working for other companies and other countries

Organizations hoping to be leaders and provide expertise in the nuclear field have a symbiotic relationship with the Canadian Nuclear Society. Very few formal training opportunities exist in many of the highly specialized fields found in our industry. The CNS can help your organizations be "lean and mean" by providing cost-effective training and professional development. However, to do so requires dedicated volunteers. Executives should be encouraging involvement in the CNS.

Even Marc Eliesen, who is not exactly the strongest proponent of our industry, recognized that companies in the nuclear business should support the Canadian Nuclear Society!

CNS *News*

Speaking with Students

Jerry Cuttler

January 15 was a fun day. I visited two high schools in Burlington, Ontario and spoke with two large groups of students.

The visits had been arranged by Troy Lassau of ORTECH International, who is a member of the CNS Education and Public Affairs Committee and also a trustee to the Halton Separate School Board. Troy had been in contact with the curriculum coordinators of both the public and separate school boards in Halton Region and had given them a list of six general topics which the CNS could address. Three schools requested speakers in January on two of the topics. Stephen Rogers undertook "Nuclear Energy – Societal Benefits and Risks" at E.C. Drury Secondary School in Milton, and I volunteered to speak on "Nuclear Energy and the Environment."

My morning talk was at Aldershot Secondary School. The science teacher, Dave McKay, had graduated from McMaster University in the early '60s. He had majored in physics and his thesis was on lithium-drifted germanium detectors. When I informed him of my background and that I had made these detectors for three years, we became instant friends. He packed two science classes (40 students) into his classroom and gave me a warm, prestigious introduction.

I started with a short excerpt from a video by Joel Barker, titled "Discovering the Future." The video pointed out that all people develop paradigms and block out information that does not conform to their paradigms. Then I proceeded with a slide presentation to explain the main barrier to public acceptance of nuclear technology – the resistance of many people, especially those with backgrounds in the humanities, who still associate nuclear technology with its first major application, weapons of mass destruction, and who are overly frightened of the risks of any exposure to radiation. I pointed out that this barrier is magnified by the media, which employed reporters with an "arts" background. Information which did not fit their paradigm of nuclear holocaust was generally blocked out. Further difficulty was caused by the media's hunt for sensational "news" that would increase readership and TV ratings.

I also referred to the phenomenon identified by C.P. Snow of the "two cultures," the technical world and the humanistic one. They had problems communicating with one another. I explained that scientists and engineers were "too technical" – they generally used jargon in public that non-technical people were unable to understand. Similarly, humanists often used terminology that technical people could not comprehend.

I described nuclear fission and radioactivity in simple terms and explained how CANDU reactors work. After pointing out the extent to which nuclear energy was used to generate electricity in Ontario, I circulated a fuel pellet and a bundle. The students were informed that one bundle cost $5,000, but had enough energy for $50,000 worth of electricity. This was enough to supply an average family in Ontario with electricity for a lifetime.

Furthermore, the radioactive waste remained in the fuel bundles, which were first stored in pools of water and later in concrete silos. I described the concept for eventual disposal of the bundles, deep in the granite rock of the Canadian Shield. I explained that only negligible amounts of radioactivity would ever reach the surface, unless there was an extremely rare cataclysmic event, such as a direct hit by a large meteor. Such a hypothetical event would cause environmental effects far worse than those resulting from the radioactivity released.

We discussed the importance of "sustainable development" for preserving our environment and referred to hydro-electric power from Niagara Falls as a good example of sustainable development. I explained that it was becoming more and more difficult to find a good hydro site that would not involve flooding a large area of land that someone was not concerned about for environmental reasons.

I showed the amount of solid and gaseous waste created each day by a coal-fired power station the size of Pickering. Burning oil would be more costly and would also produce huge amounts of waste gases. We talked about the use of natural gas for electricity generation. I pointed out that we already burn large amounts of this cleaner fuel for heating, and indicated that our supply of natural gas would probably last for only 50 years, without using it to make electricity. Oil would last a bit longer, but nuclear energy could supply our needs for many centuries, without major releases of pollution. Even with conservation, we would still need nuclear energy.

At this point, I returned to the problem of public acceptance and employed the material I had received from Sir Walter Marshall to explain the problem of vocabulary, relating to the use of the words "could" and "kill." The likelihood of nuclear accidents was compared with airline accidents, and the hazard of radiation was compared with the adverse effect of cigarette smoking. The students appeared to understand this readily. They asked how large a dose would be fatal in the short term. This led to a discussion about the relationship between dose and hazard. I explained that receiving a dose over a long period of time was less hazardous than receiving the same dose in a short time. An analogy was made with taking aspirins.

Finally, I spent some time giving examples of other applications of nuclear technology in industry, archaeology, food irradiation and medicine. I showed three slides of brain scans that compared X-ray computed tomography (CT) and magnetic resonance images with nuclear medicine brain scans. The CT and MRI scans revealed only changes in brain anatomy, while the nuclear medicine brain scans showed abnormal brain *function*. This allowed doctors to diagnose seizures, traumas and strokes, quickly and accurately.

The whole presentation lasted just under an hour, and I answered questions for a further 15 minutes before the students had to leave for the next class. The teacher was very excited and pleased with the talk. He was very grateful that I had taken the time to come out and speak with his students.

I gave the same presentation in the afternoon at M.M. Robinson Secondary School. The teacher, Mrs. Knight, was also excited to see me. She mentioned that Dave McKay of Aldershot had just called to inform her that MMR would be in for a real treat. Mrs. Knight explained that she teaches a special course on issues in society. She stimulates her students to learn the facts about social problems and get involved in creating a better world. She filled her classroom with 60 students, and we had a great time. The students were more lively here, and I felt we could have gone on and on.

I spoke with Mrs. Knight two weeks later. She told me her students were very pleased with my talk. In fact they brought in clippings about the newspaper reports on the "1 in 17 chance" of a Chernobyl-like accident at one of Ontario Hydro's 20 reactors. They pointed out the sentence, "a meltdown at Darlington . . . *could* result in 200,000 radiation-related *deaths*. . . " and were thrilled that they could understand what these news reports really meant.

I called Troy Lassau to find out what feedback he had received. He stated that all three schools were very pleased with the CNS presentations and that many invitations to visit other schools could be expected.

In conclusion, I would urge the other members of the CNS (now 800 in number) to consider sacrificing a bit of their time to volunteer to talk with the students in our schools. These people will soon be the ones making the choices that will decide the future of our technology.

Nominations for 1993-94 CNS Council

The following list of candidates has been proposed by the Nominating Committee for the 1993-94 CNS Council:

Past President	W.I. Midvidy, Ontario Hydro, Toronto
President	P.J. Fehrenbach, AECL Research, Chalk River Laboratories
1st VP	E.G. Price, AECL CANDU, Mississauga
2nd VP	J.M. Cuttler, AECL CANDU, Pickering
Secretary	S. Kupca, DND, Ottawa
Treasurer	B. Rouben, AECL CANDU, Mississauga
At Large	O. Akalin, Ontario Hydro, Toronto
	H. Huynh, Hydro Quebec, Montreal
	T. Lassau, ORTECH, Mississauga
	F. Lipsett, AECL Research, Chalk River
	A. Lone, AECL Research, Chalk River Lab.
	D. Rozon, Ecole Polytechnique, Montreal
	K.L. Smith, Consultant, Mississauga
	S. Smith, Wardrop Engineering
	J. Sobolewski, CANTECH

Paul Fehrenbach is the CNS president-elect for 1993-94.

Hugh Irvine and Bill Penn say Goodbye

Ric Fluke

Some 248 members of Ontario Hydro's ENCON Services Branch opted to take early retirement, including Hugh Irvine and Bill Penn, who are well known in the nuclear business. Both Hugh and Bill will be missed by the hundreds of staff and friends who enjoyed working during some of the toughest times of the industry – through the Porter commission, Hare commission, and until recently, the Demand/Supply Plan Hearings. Hugh's most recent position was Chief Engineer, and Bill was Senior Consultant for Public Hearings and Commissions.

Hugh joined Ontario Hydro from Canadian General Electric and managed the newly formed Nuclear Studies and Safety Department. At that time, the department Christmas party was held in the living room of his home in Ajax! Such a venue was short-lived however, as the department grew to meet the ever increasing demands of licensing new facilities. Hugh later moved on to head the Nuclear Engineering Department, and became group manager for several departments. He was later appointed Director of Design and Development Division – Generation, until the branch restructuring in 1992, when Hugh was appointed Chief Engineer. He is now relaxing with his family. Being a traditional Scot, Hugh plans to pursue his musical ambitions with a well known Scottish instrument, the saxophone.

Bill is also a former CGE employee who joined the Nuclear Studies and Safety Department to carry out studies of advanced fuel cycles using thorium and low enriched Uranium. Studies at the time indicated that Ontario would run out of economic uranium ore by the year 2000 (yeah right, eh?). He soon became manager of NSSD. Having the department picnics at his home was no problem, since he has a farm in Pontypool. These summer events are fondly remembered by kids and parents alike. He moved on to become Group Manager of Generation Planning and Development, where much of his time was taken up by the public hearings on Ontario Hydro's Demand/Supply Plan. With the branch restructuring in 1992, Bill was appointed to Senior Consultant, in charge of Public Hearings and Commissions. Bill plans to do some travelling and spend time with his family, but later, will expand his horizons as a "man out standing in his field," i.e., as a shepherd. Popular rumour, however, will see his timely return to the industry, but his rates will be higher.

News of Members

Dan Meneley, chief engineer at AECL CANDU, is off to Korea on a 10 month loan to the newly formed Korea Institute of Advanced Engineering in Seoul.

John Hewitt, one of the founders of the CNS and a former president, has joined the Electricity Branch of Energy, Mines and Resources Canada as a senior adviser.

Don Lawson, president of AECL CANDU, has been awarded the 1992 Engineering Medal for Management by the Association of Professional Engineers of Ontario (APEO) in recognition of his "successful leadership and management of one of the most complex industries in Canada".

Augustine Mao, of AECL CANDU, was presented with a 125th Anniversary of Confederation medal from the Governor General of Canada for his work with the Chinese community.

Paul Lafrenière est nommé, en juin 1992, Chef de Service "Services Techniques", à Gentilly 2 en remplacement de Monsieur Denis Delorme qui a quitté Hydro-Quebec pour rejoindre l'équipe du projet Cernovoda en Roumanie.

Martial Doyon est nommé, aussi en juin 1992, Chef de Service "Formation Technique" a Gentilly 2 en remplacement de Monsieur Claude Bourbonnais qui, aussi, a rejoint l'équipe du projet Cernovoda.

News of the Branches

Almost all of the ten local branches of the Canadian Nuclear Society have been active this season. Following is a summary of some of that activity.

Bruce

Although the Bruce branch has not held any meetings lately chairman Karel Mika organized a letter writing campaign in support of the rehabilitation of the Bruce 'A' station and has set up a group to counter "misinformation" in the media and to offer speakers to local groups.

Central Lake Ontario

Members of the Central Lake Ontario were involved in the CANDU Maintenance Conference last November and have been very occupied in getting the Darlington units on line. Chairman Dan Meraw reports that a special meeting is scheduled for March 30 with a talk on "Nuclear Power Plant Training Simulators" to be held at Ontario Hydro's Eastern Nuclear Training Centre.

Chalk River

Chairman Aslom Lone and his group have organized a full schedule of meetings this season. In January, Don Lawson, president of AECL CANDU spoke January 14; Sean Conway, Liberal MPP for Renfrew and a former member of the Ontario Cabinet gave his views on "Current Issues Concerning Ontario Hydro on February 3; and just a week later, February 10, Roxanne Summers, of the Canadian Nuclear Association reviewed the CNA public information program. On March 17 Dr. W.H. Hannum of the Argonne National Laboratory in the USA was scheduled to speak on the "USA Integral Fast Reactor Program".

Golden Horseshoe

The Golden Horseshoe branch, based at McMaster University in Hamilton, and re-vitalized under co-chairmen Jeremy Whitlock and Glenn Harvel, held its first meeting as a trip to Darlington and a seminar by Fred Dermarkar. In January the focus was International Marketing with Mike McAskie of AECL CANDU.

Manitoba

The Manitoba branch, centred at the Whiteshell Laboratories, is regrouping. A successful lunch-hour meeting was held in the fall.

New Brunswick

Paul Thompson is the new chairman of the New Brunswick branch. The next meeting is scheduled for late March with J. Nathwani of COG speaking on Risk.

Ottawa

Under chairman Stefan Kupca of DND two meetings were held, in December with a presentation by Andrew Stirling of AECL Accelerators, and in February with Paul Fehrenbach of AECL Research speaking on AECL's Advanced CANDU R & D Program with some members of the CNS executive attending. A closing dinner meeting is scheduled for April 29.

Quebec

Hong Hyunh, of AECL Montreal, and a member of the CNS Council, is leading the effort to re-organize the Quebec branch with more focus on members at the Gentilly station.

Saskatchewan

The luncheon meeting in December, with Dr. Tore Straum as the speaker drew almost 100. Scheduled for March 17 is Dr. Margaret Maxey on "Ethics in Environmental Cleanliness". Chairman David Malcolm presented a brief to the FEARO panel examining the McArthur River exploration program.

Toronto

The CNS's largest branch, Toronto, continues its successful Science and Technology seminar series. In January Dr. Norm Gentner of AECL Research spoke on "Update on the Health Effects of Chernobyl: Fact or Fiction", and in February, Dr. Brian Stewart provided "An Update on the Darlington Fuel Damage Problem". Scheduled for March 23 is Dr. Rosalyn Yalow, a Nobel prize winner in medicine, speaking on "The Societal Benefits and Risks of Radiation". Planned for April 20 is Dr. Rene Levesque, recently retired president of the Atomic Energy Control Board, speaking on "Nuclear Regulation in the 1990's".

Membership Time

Membership fees for 1993 are now overdue. If you have not sent in your cheque (or credit card number) do so as soon as you have finished reading this.

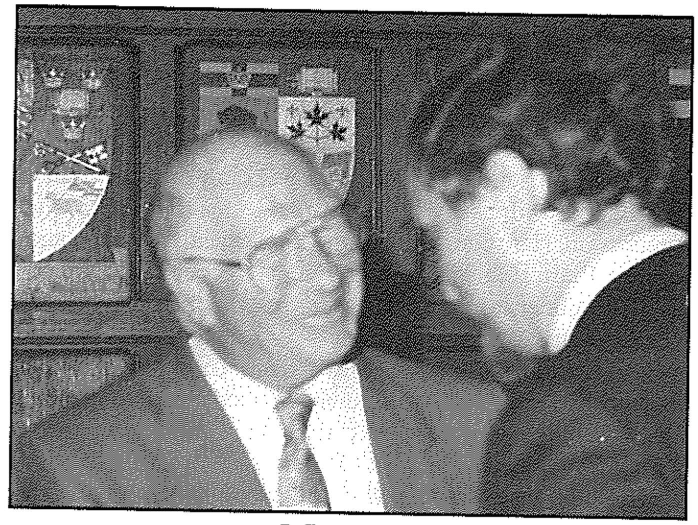
If you are not yet a member, copy the form included in this issue and send it in. Members enjoy discounted registration fees at CNS meetings, receive the *Bulletin* quarterly, and, most important, share in the fellowship and development of the Canadian nuclear community.

R.E. Jervis Award

The Canadian Nuclear Society is sponsoring an award to recognize the contribution of Prof. Robert E. Jervis who retired from the University of Toronto last year. Dr. Jervis' research career centred on radiochemical and radioactivation techiques and their applications to interdisciplinary fields.

The award has a value of $500 and will be given annually.

Candidates must be a full-time graduate student at a Canadian university, pursuing research involving the development of radiochemistry or its application and be a Canadian citizen or landed immigrant.



R.E. Jervis

For further information contact Prof. G.J. Evans, U. of T. Tel. (416) 978-1821; FAX (416) 978-8605.

Calls for Papers

International Topical Meeting on Safety of Advanced Reactors
Pittsburgh, USA – 17-21 April 1994

Abstracts (300 to 600 words) should be sent to:
D. Squarer
Westinghouse Science and Technology Center
1310 Beulah Road
Pittsburgh, PA., USA 15235-5098
Tel. (412) 256-2063
FAX ((412) 256-1348

DEADLINE IS 10 JUNE 1993

△

8th International Conference on Radiation Shielding
Arlington, Texas – 24-27 April 1994

Abstracts should be sent to:
Dr. Richard M. Rubin
Dallas, Texas
Tel. (214) 812-8247
FAX (214) 812-8687

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RECOD '94 4th International Conference on Nuclear Fuel Reprocessing and Waste Management
London, England – 24-28 April 1994

Abstracts should be sent to:
RECOD '94 Conference Secretariat
Tel 071-828-0116
FAX 071-828-0110

DEADLINE IS 31 MARCH 1993

Book Review

Qwerty and Shrdlu And All That

The Design of Everyday Things, D.A. Norman, Doubleday Currency, New York, 1990 (ppbk).
Reviewed by Keith Weaver

A somewhat effusive quote praising this book appears on its back cover. The quote is from Tom Peters and it almost deterred me from buying, let alone reading, the book. Fortunately for me, I bought and read it.

In what now seems almost another life, David Mosey and I studied and reported on something we referred to as "institutional failure" (and which Norman seems to refer to as "system failure"). That work led me to authors such as Reason, Rasmussen (a different one), Searle, and a lot of other people nobody else seems to have heard of. This earlier work made me familiar with the questions that Norman unveils, those maddeningly vague kinds of question such as, How much can someone remember? How do people do things? Why do people sometimes do things incorrectly? How does one define an error or mistake? However, I wasn't prepared for the overall impact that this innocuous-looking volume would have.

For anyone who knows little or nothing about human factors, this book is likely to be an eye-opener. Ever find yourself struggling to determine how to operate a coffee machine, a photocopier, someone else's CD player? Norman comes out bluntly. It's not your fault that you have difficulty. It's more likely the result of bad design. He supports his thesis in a most engaging way by examining a number of everyday things which display their own "psychopathology." They range from telephones, to faucets, to doors, to light switch, to electric appliance controls, to . . . .

In fact, it seems that there are surprisingly few well designed products out there, and the book sets out to lodge something of a complaint. Products may meet any one of the requirements of cost, aesthetics, durability, ease of manufacturing, or usability. The first-mentioned of these usually wins out, the last is usually left out. Having set up this situation, Norman then takes the reader on a fascinating tour that includes a description of how people do things, the nature of tasks, and how the good design of a product takes advantage of both the nature of the task and the nature of humans. The things that stand out here are the down-to-earth presentation, the forthright nature of the complaint, and the epidemic nature of the disorder which the author decries. Human factors considerations are either overlooked, paid lip service, swamped by corporate or design excesses, or ineffectually tacked on when it's too late.

It takes very little time to become engrossed in this interesting book. One might easily agree with the author and utter a concerned tut-tut or two. Eventually, however, a question may rise up. When was the last time you had the opportunity to talk to a human factors expert in the course of your work, i.e., in a professional capacity to help fashion, improve or optimise your product, the fruits of your labours? At that point, you may take a renewed interest in what Norman has to say. You may even have to backtrack a bit. Some of his statements may seem questionable. But there is a very considerable amount of food for thought.

This is an extraordinary, revealing and accessible little book. It also raises a couple of questions: Is human factors as much a poor relation in the nuclear industry as Norman seems to feel it is everywhere else? Is there some reason why the local human factors people haven't been flogging this engaging book wherever they can, or at least ensuring that each of our industry's libraries has a few copies?

Domaratzki Heads Insag

A Canadian now heads the most prestigious nuclear safety group in the world.

Zigmund Domaratzki, Director-General, Reactors, at the Atomic Energy Control Board was chosen as chairman of the International Nuclear Safety Advisory Group (INSAG) of the International Atomic energy Agency last fall. INSAG is a special, very senior-level, group first established by the IAEA after the Chernobyl accident of 1986 to advise on broad generic aspects of the safety of nuclear reactors.

Canada's first representative on INSAG was Dr. Dan Meneley, then a professor of nuclear engineering at the University of New Brunswick, now chief engineer at AECL CANDU. Domaratzki joined INSAG in 1989 when the IAEA reconstituted the group for a further three years. Last summer when it became time for a subsequent three year arrangement Domaratzki was reappointed and shortly thereafter named acting chairman. That position was confirmed in the fall.

INSAG has produced a number of reports, of which the best known is INSAG-3, "Basic Safety Principles for Nuclear Power Plants", published in 1988. Recently the group has released INSAG-7, a further review of the Chernobyl accident.

Comment

The Objectivity Crisis

George E. Brown

Ed. Note: *Last fall the* American Journal of Physics *ran an essay by congressman George E. Brown, Jr., chairman of the House Committee on Science, Space and Technology in the USA, entitled "The Objectivity Crisis". Excerpts from that essay were printed in the publication* Physics and Society *published by the American Institute of Physics. A leading member of the CNS noted the latter, read the essay, and was sufficiently impressed that he passed them on to the CNS* Bulletin *for our consideration. We are pleased to present here our excerpts from the original essay. Much of the full article referred to the particular situation of research, especially physics research, in the USA. However, Brown presents some pertinent thoughts applicable to science and technology and their practitioners everywhere. Following, with acknowledgement to the above journals and thanks to the American Institute of Physics, is our excerpt.*

Science does not exist in a vacuum; it is inextricably linked with nonscientific elements of society – politics, history, economics, emotion, luck. This is obvious, though it is often not adequately appreciated. More significant, and more troubling, is that we have elevated science – or, more precisely, scientific knowledge – to a position of predominance over other types of cognition and experience; that we have, unconsciously and ironically, imbued science with more value than other types of understanding which are overtly and explicitly value based.

The Czech philosopher and playwright (and president) Vaclav Havel has called this the "crisis of objectivity", because we have subjugated our subjective humanity – our "sense of justice ... archetypal wisdom, good taste, courage, compassion and faith" to a process (scientific research) that not only cannot help us distinguish between good and bad, but strongly asserts that its results are, and should be, value free.

We already have much of the knowledge and many of the technologies necessary to: decrease population growth; increase energy efficiency; reduce and recycle wastes; and, improve public health and education throughout the world. The real problem is implementation: adapting our social and economic systems so that they are capable of assimilating and using this information and hardware. There has never in human history been a long-term technological fix. We will only change this progression when we understand that our problems are those of human or cultural behaviour, not inadequate machines.

The current debate over issues such as global climate change; energy production, consumption and conservation; and disposal of hazardous wastes, all hinge on the expectation that science will provide data that will dictate policy, or provide technology that will obviate the consequences of our past actions. But science – which always generates new questions in answering old ones – is often uniquely unsuited for these tasks.

The pursuit of wisdom in human culture has embraced truth, beauty, and justice as the highest goals. In the pursuit of science, truth, about the observable world, is the single highest goal, beauty is a serendipitous by-product of the search for truth, and justice is considered outside the realm of scientific consideration. But our philosophers assert that, without justice, human societies are prone to violent conflict and self-destruction as they compete for the resources necessary for survival, The problem then is to visualize and create linkages between the search for scientific truth and the desire to achieve justice in society.

If we are to reduce inequity of social and economic opportunity throughout the world (that is, to achieve justice), and reverse the degradation of the earth's ecosystems (that is, further our capacity for self-realization and survival), then we must adopt specific goals that define an overall context for research; zero population growth; less waste; less armed conflict; less consumption of nonrenewable resources; less dependence on material goods as a metric of wealth or success.

My personal view – subjective in the extreme – is that the ultimate enrichment of the human spirit comes from our ability to expand our realm of experience and knowledge. Scientists must seek to share the privilege of their enrichment with others, not by promising more, faster, stronger, machines, but by sharing what they know and how they feel. This demands a renewed commitment to education as the ultimate mechanism for individual empowerment, and a critical prerequisite for social justice. This is a commitment that all scientists can make, in their own backyards, starting now.

Deadline

The deadline for the next issue of the CNS *Bulletin*, Vol. 14, No. 2, Summer 1993, is 28 May 1993.

Canadian Nuclear Society

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- ☐ QUEBEC
- ☐ SASKATCHEWAN
- ☐ TORONTO
- ☐ CENTRAL LAKE ONTARIO (Pickering, Darlington, Port Hope, Peterborough)
- ☐ USA AND INTERNATIONAL

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- ☐ LAC ONTARIO CENTRAL (Pickering, Darlington, Port Hope, Peterborough)
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☐ ÉTUDIANT(E)	20.00
☐ RETRAITÉ(E)	30.00
☐ INSTITUTIONNELLE	55.00

† Les membres qui enverront leur application après le 1er septembre 1992, seront automatiquement transférés à l'année 1993. Les frais de la TPS sont inclus dans les frais d'inscription.

Si vous ne faites pas parti des membres de la SNC et que vous vous êtes inscrit à l'un des événements au calendrier des activités de la SNC, vous avez alors droit à un rabais de 15.00 $ sur le montant de votre première cotisation. Veuillez simplement déduire 15.00 $ sur le montant. ______________
Indiquer le nom de l'activité

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Veuillez compléter et retourner à
Société Nucléaire Canadienne, 144, rue Front ouest, Ste 725, Toronto, Ontario M5J 2L7
Téléphone (416) 977-7620

IMPRIMÉ SUR DU PAPIER RECYCLÉ

Calendar

1993

April 2-3 — **CNA/CNS Student Conference**
École Polytechnique, Montréal, Québec
contact: Dr. D. Rozon
Tel.: 514-340-4803

April 21 — **Seminar, "Fusion Energy: Technological Challenges and Opportunities for Industry"**
Toronto, Ontario
contact: Shayne Smith
Tel.: 416-673-3788
Fax: 416-673-8007

May 17-19 — **CANDU Reactor Safety Course**
Toronto, Ontario
contact: Joel Almon
Ontario Hydro
Tel.: 416-506-6889

June 2-4 — **4th International Conference on Simulation Methods in Nuclear Engineering**
Montreal, Quebec
contact: A.F. Oliva
Ontario Hydro
Tel.: 416-592-7676

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

June 22-24 — **Annual Conference: Canadian Radiation Protection Association**
Toronto, Ontario
contact: Shirley Coyne
Tel.: 416-683-7516

June 28 - July 3 — **Nuclear Energy and Human Safety**
Nizhni Novgorod, Russia
contact: Andrei Yu Gagarinski
Nuclear Society RRC, Moscow
Fax: 007 (095) 196-2073

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

September 8-10 — **8th Annual Symposium of the Uranium Institute**
London, England
contact: Uranium Institute, London
Fax: 071-225-0308

September 13-14 — **International Conference on Expanded and Rolled Joint Technology**
Toronto, Ontario
contact: G. Kharshafdjian
AECL-CANDU
Tel.: 416-823-9040, Ext. 2102
Fax: 416-823-8006

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

September 20-24 — **7th International Conference on Emerging Nuclear Energy Systems**
Makuhari, Japan
contact: Dr. T. Hiraoka
Japan Atomic Energy Research Institute
Tokai-mura, Japan
Tel.: 81-292-82-5517
Fax: 81-292-82-6122

September 27-30 — **Topical Meeting on the Technical Basis for Measuring, Modelling and Mitigating Toxic Aerosols**
Albuquerque, New Mexico
contact: Mark Hoover
Inhalation Toxicology Research Institute
P.O. Box 5890
Albuquerque, NM, USA 87185-5890

October 3-8 — **International Nuclear Congress – INC '93**
Toronto, Ontario
contact: Dr. Ben Rouben
AECL-CANDU
Tel.: 416-823-9040
Fax: 416-823-8006

November 14-19 — **ANS Winter Meeting**
San Francisco, California
contact: Dr. W.I. Midvidy
Ontario Hydro
Tel.: 416-592-5543
Fax: 416-978-0193

1994

April 3-6 — **4th International Topical Meeting on Nuclear Thermal Hydraulics**
Taipei, Taiwan
contact: Justice Liu
PG & E, San Francisco, CA, USA
Tel.: 415-972-4592

April 17-30 — **International Meeting on Advanced Reactor Safety**
Pittsburgh, Pennsylvania
contact: D. Squarer
Westinghouse Electric Corp.
Tel.: 412-256-2063

April 24-28 — **4th International Conference on Nuclear Fuel Reprocessing & Waste Management**
London, England
contact: British Nuclear Forum
22 Buckingham Gate
London, SW1 E 6LB, UK

1994 cont.

April 24-27 **8th International Conference on Radiation Shielding**
Arlington, Texas
contact: Richard Rubin
Dallas, TX, USA
Tel.: 214-812-8247

April 27-29 **Chemistry in Water Reactors**
Nice, France
contact: French Nuclear Society
Bureaux 48, rue de la Procession
F 75724 Paris Cedex 15, France

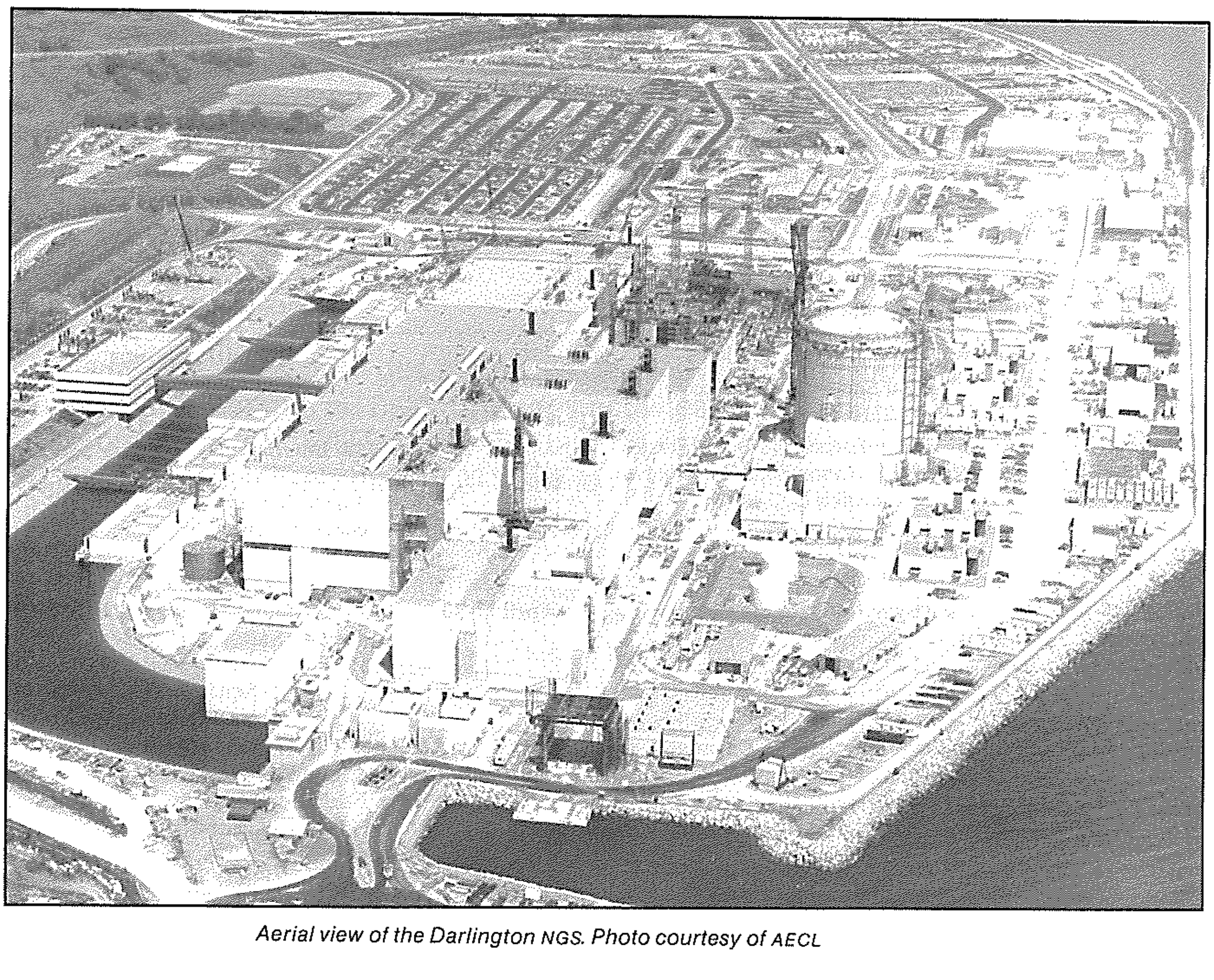
May 1-6 **9th Pacific Basin Nuclear Conference**
Sydney, Australia
contact: 9PBNC Conference Secretariat
Fax: INT 61-6-273-2918

May 30 - June 2 **International Conference on Nuclear System Thermalhydraulics**
Pisa, Italy
contact: N. Spinks
AECL Research, CRL
Tel.: 613-584-3311

June 5-8 **CNA/CNS Annual Conference**
Montreal, Quebec
contact: Kathy Murphy
CNA/CNS
Fax: 416-979-8356

June 13-15 **Steam Generator Conference**
Toronto, Ontario
contact: D. Lister
UNB
Tel.: 506-453-5138

October 19-21 **3rd International Containment Conference**
Toronto, Ontario
contact: D. Pendergast
AECL-CANDU
Tel: 416-823-9040
Fax: 416-823-8006



Aerial view of the Darlington NGS. Photo courtesy of AECL