CANADIAN NUCLEAR SOCIETY

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DE LA SOCIÉTÉ NUCLÉAIRE CANADIENNE

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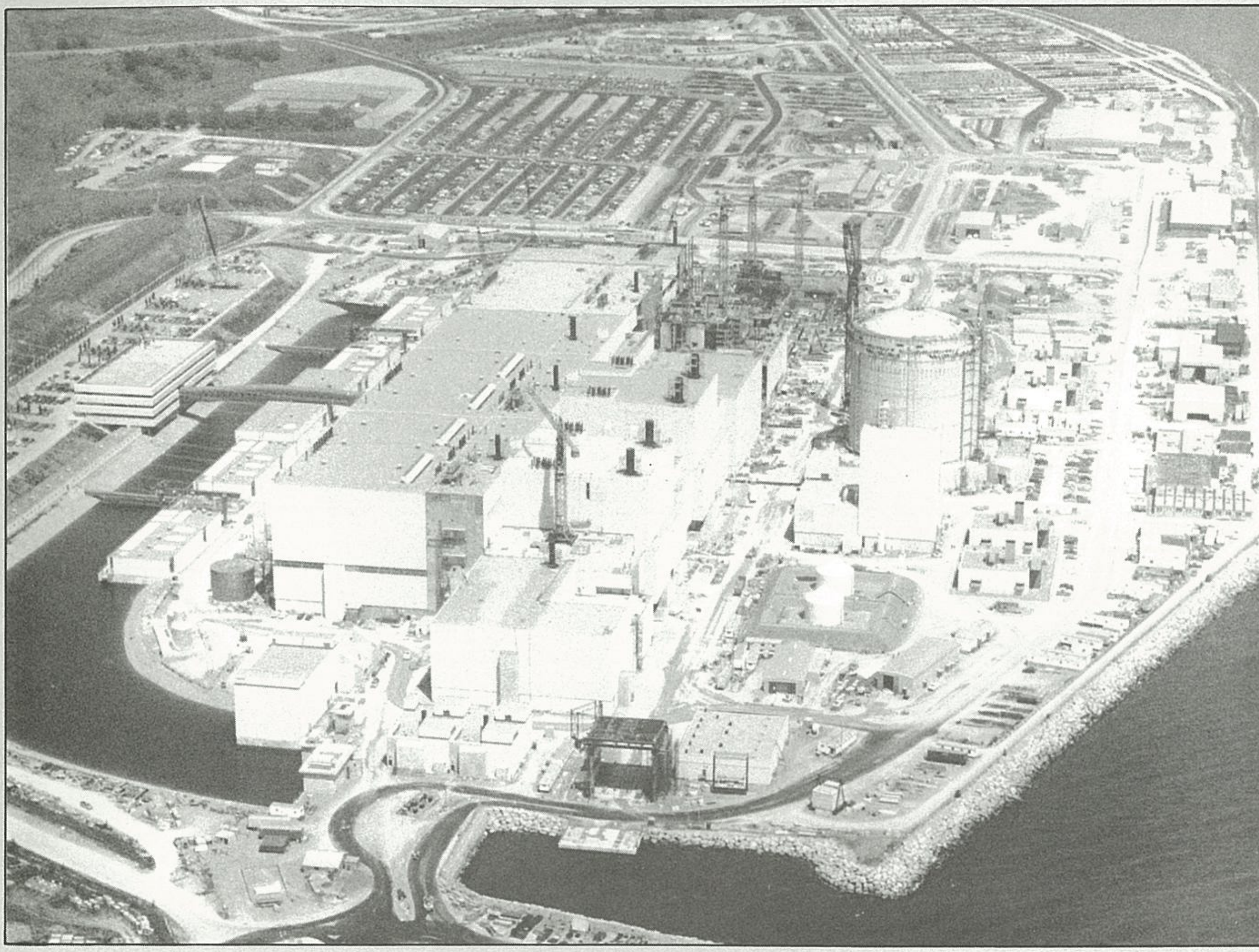

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Cover photo

The cover photograph shows an aerial view of the Darlington NGS (taken in 1988 when construction was still underway) in recognition of the two major papers on the Darlington fuel damage problems in this issue.

Once again we thank Lyse Menard of AECL's head office for this photograph.

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Needed – A Disciplined Industry

The environment for nuclear activities in this country remains unsettled. Perhaps that reflects the general malaise in the economic and political spheres but there are internal problems as well.

There are some bright spots. The recent announcement of two more CANDU units in Korea is very welcome, for both economic and morale benefits. Also, there now appears to be some light at the end of the long, dark tunnel in which the Darlington NGS has been mired for the past two years.

Nevertheless, with the continuing nuclear moratorium in Ontario and no realistic, early, prospects for nuclear power plants in other provinces, the future of the domestic nuclear power scene is uncertain at best. At the same time the uranium industry is feeling the consequences of the world-wide economic slowdown, with over-capacity and low prices.

Despite the encouraging news about the complex problems at Darlington, that plant will continue to be the Achilles heel of the Canadian nuclear program until all four units are operating as intended. It is quite reasonable for politicians and the public to say "no" to any further nuclear plants when they are repeatedly faced with large electrical power rate increases just to pay the debt on a non-operating plant. Arguments that the problems were unforeseen are not sufficient. They should have been foreseen.

The nuclear industry is dealing with large, complex systems, which involve thousands of people. It must become more disciplined. Every item, every step, every operation must be integrated with the whole. The aircraft and electronics industries can do it, why not ours?

This is primarily a technical problem – albeit requiring appropriate organization. There are well established principles and techniques for ensuring reliability and quality. Unfortunately, the nuclear industry has tended to rely on the competence of its individuals (which, thankfully, has been very high) – refusing to acknowledge that in large, complex operations involving many people, individual competence is not enough.

No one likes to lose their individuality – and it is not necessary. Just as members of a team can be themselves while still working together so can all the capable people in the nuclear industry. But it will take discipline.

Taking a Stand

It took some soul-searching by members of the CNS Council and, particularly, considerable determination and effort by two members, but the CNS has submitted a Brief to the Ontario hearings on Ontario Hydro's Demand/Supply Plan. Treasurer Jerry Cuttler took the initiative, convincing Council to proceed, and preparing the first draft. Aslom Lone, chairman of the Chalk River Branch, picked up the task, redrafted the document (with input from his colleagues) and circulated it to many interested people. Miraculously, it survived all this. You can read the final product in this issue.

It would be foolish to believe that this one submission will determine the outcome of the hearings. Nevertheless, the CNS Brief does offer a concise argument why nuclear should be considered for the future electrical generation needs of Ontario. More importantly, it has brought a number of members together to tackle a social and political issue that can affect all in the nuclear field. The Society should be doing more of this.

In this issue

This issue of the *Bulletin* is a "meaty" one. Most of the articles are longer than our usual practice and deal with substantive topics.

Two of the four major papers deal with broad, non-technical, issues related to the use of nuclear energy. The thoughtful observations by Dr. Kenneth Hare (of Ontario Nuclear Safety Review fame), which were presented to the opening session of the joint CNA/CNS Annual Conference, should be required reading for all interested in nuclear science, technology and industry. Mirroring those thoughts are the intriguing arguments of Archie Robertson on the ethics of the use of nuclear energy.

Among the many interesting topics at the successful CNA/CNS conference was the first open technical report on the problems at the Darlington NGS. The two overview papers, by Brian Stewart of Ontario Hydro and Ed Price of AECL CANDU, provide insightful, clear and concise accounts of the investigations into the complex fuel damage problems.

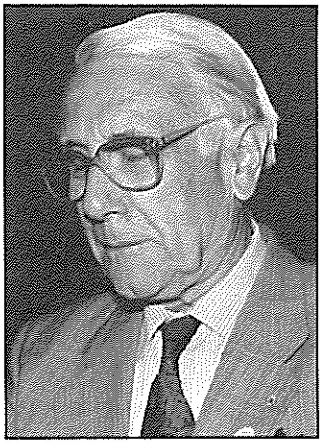
The new CNS Council has been active since it was elected at the June AGM and some of its accomplishments are reflected in the usual section on CNS News. In particular, members should note the Brief which was submitted in mid-September to the Ontario EAB hearing on Ontario Hydro's Demand/Supply Plan.

As always, your comments and input are welcome.

Nuclear power: A place in Canada's future?

F. Kenneth Hare

Ed. Note: *Following is most of the text of Dr. Hare's opening, keynote, address to the CNA/CNS Annual Conference in Saint John, NB, June 8, 1992.*



Dr. Kenneth Hare.

Mr. Chairman,
Ladies and Gentlemen:

I am grateful for the opportunity – and honour – of opening the technical discussions at CNA's annual bash. I shall begin with some apologies; go on to speak the truth as I see it; offer some advice – and then beat a hasty retreat westward.

The apologies first.

Through no plan of my own I have twice played the rôle of officially-sponsored snooper into this industry's affairs. In early 1977 Alastair Gillespie, then Minister of Energy, Mines and Resources, and his Deputy, Gordon MacNabb, asked me to chair a quick (and inevitably dirty) look at nuclear waste disposal in Canada. My colleagues were the late Jim Harrison and Archie Aikin, whom you must mostly know. Our report, which went to Alastair a day early, on August 30th, 1977, was hastily prepared. But AECL and Ontario Hydro have subsequently acted so well on our advice that Canada now appears among the world's leaders in intermediate storage and final disposal technology.

Then David Peterson and his Cabinet appointed me as sole Commissioner of the Ontario Nuclear Safety Review in 1986-88, in the wake of Chernobyl. Currently I serve as Chair of the Technical Advisory Panel on Nuclear Safety of Ontario Hydro (TAPNS), and as a member of the Technical Advisory Committee of AECL Research; so I'm still there, peering over the fence – not, in my case, an exclusion fence.

I want to make five points about this personal record:

First: I have always insisted that I act independently, with no instructions from anyone in the industry, government, or interest groups.

Second: This independence has been consistently respected by the industry representatives and public servants with whom I and my colleagues have dealt, even when our findings were against what they saw as their best interests.

Third: I have had freedom of access to all sites, and all documents of which I have knowledge.

Fourth: I have relied on numerous consultants, not least your President, to train me, a clueless outsider, in the technical aspects of the industry.

Fifth: And finally, my concern has been for the safety of the public, and of the exposed workforce of the power-producing utilities; I have had no experience at the mining and refining ends, and only a little in the research phase.

When I began these studies I was sceptical as to the safety of nuclear technology. As far as the power-production was concerned, I thought that the trouble lay partly up front, in the mine tailings problems, and as regards the safety of underground miners; and partly at the back-end, in the disposal of spent fuel, or of high level processing wastes.

But fifteen years of exposure, in which I have been given unrivalled access to the industry's inner workings, have changed my view. I now see waste disposal as a straightforward task needing technical care and foresight, but not presenting insuperable difficulties. Much of the public comment in this area is science fiction.

Much of the public comment [on waste disposal] is science fiction.

On the other hand, I may have underestimated the problem of reactor safety. It was operational reactor failure that led to the accidents at Sellafield (then called Windscale, and not a power reactor), Three Mile Island and Chernobyl. We have not been immune in Canada; the NRX and NRU events at Chalk River remind us of that. And CANDU reactors, under operational conditions, are not immune from failure.

The long-term future for nuclear power – and this is my thrust today – depends on answers to a short series of tough questions:

1. can the power utilities maintain their present standards of safe performance; and, in some cases, can the standards be improved?
2. can the body politic be persuaded that these standards are adequate?
3. can the costs of safe design, construction, operation, waste disposal and decommissioning be kept sufficiently low to maintain nuclear power's competitive edge, if properly reckoned?
4. and can international safeguard programs prevent the diversion of skills and materials into military misuse, even in rogue countries that notoriously disregard the Non-Proliferation Treaty?

Let me turn first to safety performance.

In Canada, since the accidents in the research reactors in Chalk River, there has been no event that has endangered the public, although within the CANDU plants there have been significant failures that increased the radiological risk to the workforce. Normal operation has exposed neither the workforce nor the public beyond the Atomic Energy Control

Board's limits; in fact the operational target of not exceeding one per cent of those limits has almost always been reached or bettered.

It is important to keep check on this foursome of situations; one must consider workforce and public safety separately, and how both may fare in accident and normal conditions. The study of twenty years of power reactor operation enabled the Ontario Nuclear Safety Review to confirm that all four combinations have yielded reassuring answers. I believe this still to be true as regards safety.

The proof of the pudding must be in the eating. We have had no severe accident, so we can apply this rule only to overall operational experience. The measure must be the exposure, health and mortality statistics of the relevant groups, and these have now accumulated to the point where one can make some generalizations:

(i) The exposed Canadian reactor workforces appear to have suffered little or no detriment from working within the reactor buildings. Average occupational exposures in the largest utility, Ontario Hydro, are now well below world average occupational values, and far below the AECB limits and International Commission on Radiological Protection recommendations. Mortality from cancer of all kinds among the Ontario Hydro exposed workforce over the years 1971-1989 was only 66 per cent of that of the equivalent group in the general Ontario public – in spite of at least double overall exposure. AECL's experience has also been excellent.

(ii) Releases of radioisotopes (chiefly tritium, carbon-14, noble gases and certain particulates) from venting and cooling systems of CANDU reactors have been kept on an annual basis within or below 1 per cent of the permitted limits at all stations, though there have been brief episodes of higher tritium release following heavy water spills.

(iii) There is no comprehensive monitoring of public exposure as the result of these releases, but AECB-sponsored epidemiological analyses of children born or resident near Pickering NGS and Bruce NPD have shown slightly (but not significantly) elevated mortalities from leukemia, and in the case of Pickering NGS a significantly elevated incidence of Down syndrome. In the latter case, a similar excess occurred in eastern Ontario, far from any reactor. These clusters of cases are unlikely to have been due to the small releases from the reactors; but they have been given much publicity, and raised public concern. The same is true of rumours concerning Gentilly-II in Quebec, which have been shown to be unfounded.

The overall health and safety record in Canada is thus good, though a more targeted form of epidemiological survey is needed to eliminate any doubts about leukemia and Down syndrome incidence near the Ontario reactors. Epidemiological and medical standards alone do not justify such attention, since there is no evidence of excess exposure to radiation, but public concern does – and should be catered to, in my own judgement.

The care with which this monitoring and research effort is conducted is praiseworthy, and the results convincing to people who take the trouble to read them. On the down side, I have heard responsible people remark that all this attention to health effects must mean that the industry expects an adverse impact. People find it hard to believe that public corporations – and all our nuclear operators are just that, agents of public policy – can behave responsibly.

The damage done to public opinion by the Chernobyl disaster was enormous. My own appointment as Commissioner of the ONSR arose directly from the event, and my Review's findings that no accident of this sort could occur in a CANDU reactor was scoffed at by some commentators. On the other hand, the very remote possibility of other forms of severe accident in a CANDU, mentioned in the ONSR report, was seen as an over-optimistic bit of window-dressing.

In the same way, the assessments of the consequences of Chernobyl by IAEA and other bodies have been written off as white-washing, while claims of heavy casualties and impending cancer deaths continue to be widely circulated, not least by officials in Belorus and Ukraine. The reality was bad enough; the imagined consequences are far worse. I see no sign as yet that public opinion has shifted towards the more sober views that I am sure reflect the truth.

The damage done to public opinion by the Chernobyl disaster was enormous.

Chernobyl is not alone in casting doubt on Canada's seemingly sound performance. I have just spoken of the evidence of good health and low cancer mortality of the Canadian exposed workforce. I also spoke of the probably accidental clustering of leukemia and Down syndrome incidence near certain Canadian reactors. Speculation about both results has been prompted by several foreign studies. In the United Kingdom, for example, elevated mortalities from childhood leukemia have been reported near the Sellafield, Aldermaston and Dounreay nuclear complexes.

Most recently, findings of a significant dose-response relation for leukemia incidence among exposed British workers have led to questions about the excellent record among Canadian workers (even though the overall proneness of the British group was still below that of the public at large). Much less attention has been devoted to optimistic findings about French workers, due to Catherine Hill and Agnès Laplanche, and to the giant Jablon et al. U.S. Cancer Institute study, which involved almost a million exposed workers – without finding any evidence of adverse effects. In this field, only bad news gets media attention; and Canada's highly responsible watchdogs get little credit for their high standards of worker and public protection.

Also crucial to the future of the power utilities is the regulatory process. The Atomic Energy Control Board provides, under federal statute, a thorough and competent system of regulation. Its resources are being progressively augmented, and the vigilance with which it inspects the operating reactors has much increased. The system is, as you must all know, one that has European roots, rather than American; the AECB declares the standards that have to be maintained, and the operators have to devise ways of meeting those standards. Subsequently they must demonstrate compliance, and the AECB scrutinizes that compliance with increasing rigour, on an arms-length basis. The entire process is open to public inspection.

I remain strongly opposed to a prescriptive approach to regulation. It is becoming increasingly difficult, however, to maintain this position. In software quality assessment, for example, it is difficult for the AECB to avoid critical scrutiny that does not involve suggested redesign of the software.

We have to see regulation through international spectacles, too. The shocking condition of the industrial equipment in eastern Europe and in the C.I.S. became apparent as the diplomatic thaw proceeded. Already the IAEA has moved towards a set of standards against which an upgrading of the region's reactors can be judged, and some Canadian individuals and members of this Association are already involved in the process. I welcome this, because failures of reactors anywhere in the world affect opinion about the generic safety of the technology; and if the accident is severe enough, as at Chernobyl, radioisotopes may be spread hemisphere-wide. We all have a large stake in what happens east of the old Iron Curtain.

Let me now turn to costs. If nuclear technology did not require heavy investment in safe design, construction and operation, it would unquestionably be the cheapest source of large-scale power. No doubt this is why the Soviet Union's RBMK reactors appear to western eyes to be so poorly designed. But western reactor design, and especially that of CANDU, with its need for fast shutdown systems, requires a high investment in massive concrete containments, expensive control, monitoring and back-up systems, and elaborate operator training. Hence initial costs are high; moreover, a large, but unspecified, part of the total is incurred by the installation of safety systems.

Canadian reactors pose this question inescapably. Because a large loss-of-coolant accident can induce a rapid power transient, engineers have had to build super-efficient high-pressure heat transport systems, which are needed in any case to generate electric power. But they have also had to design and build costly emergency core cooling systems, strong containments and the impressive vacuum buildings that are unique to Ontario's multiple-unit stations. All these stand idle unless and until a loss-of-coolant occurs. The necessary review processes are slow and, in my eyes, cumbersome. This adds to the cost.

Canadian thinking about these high costs, and expert judgements about their acceptability, have assumed high capacity factors – which in turn have depended on reliable full-power refuelling, and good performance by all process and safety systems. Point Lepreau, N.B., has fully justified these high hopes. Since its commissioning nine years ago it has achieved a capacity factor of 94 per cent, a figure that puts it at the top of the world league. But other CANDU reactors, especially older units, have had many recent problems. Pressure tube failures have led to costly replacement programs and shutdowns of entire units. Problems of availability have also occurred in emergency core cooling systems and containment. These stand-by systems have suffered from failures of conventional equipment, having nothing to do with nuclear technology itself. A higher level of preventive maintenance should have been in place in the early years of CANDU operation. All these failures have added substantially to the real cost of CANDU-generated electricity.

It is obvious, therefore, that tighter maintenance standards, and a higher reliability level of all components, are needed if capacity factors are to be maintained at economically sound levels. And clearly the search for tighter operating standards must include attention to the human factor. It would be nice if Canadians could feel that the maintenance crews on their stations were in what Maytag claims is the fate of its washing-machine staff: that they are bored-stiff at having so little to do! Canada is unfortunately far from that situation.

Tighter maintenance standards and a higher reliability are needed.

This question is not just economic. Of course rising costs weaken the case for future nuclear development. But there is also the safety question. I and my colleagues have seen no threat to public safety in recent CANDU performance. But I agree with those who say, that failures in process systems (which incur revenue losses as well as repair costs) imply that comparable failures might occur in safety systems. High capacity factors are – or ought to be – evidence of a healthy and well-maintained system, in which the public's interest in low power costs can be accompanied by confidence that the system is being safely operated.

* * *

Listening to myself talk, I seem to have concluded that the industry has done a pretty good job in protecting health and safety, but is now facing a worrying need to update – at high cost – the older power reactors. That is not at all the conclusion reached long ago by the anti-nuclear activists, whose views have carried the day with at least two provincial governments, including that which controls most of the country's reactors. Nor is it the view conveyed by the industry-sponsored television commercials, which convey an impossibly soothing image that in my view is a quite unsuitable message to convey to the public that actually owns the reactors.

The usefulness of nuclear fission as the prime source of our electrical base load, at least in certain provinces, ought to depend on a dispassionate analysis of its merits and failures. I have tried, over a decade and a half, to apply this rule to the question of safety. I believe I have been able, with much help from others more expert than I, to influence the way in which matters are being handled in the utilities, in the nuclear generating stations, and by the Atomic Energy Control Board. The industry and its regulators, that is to say, have listened to what I have said, read what I have written, and allowed me to go on looking in from outside.

On the other hand, I have had *no* influence on the anti-nuclear lobby, which sees me simply as an ally of the industry; and little if any on the provincial governments.

Canada simply cannot afford to do without the use of nuclear energy. My original field of expertise was climate, and especially climatic change. I can assure you that the greenhouse effect is no illusion, and that to reduce the use of carbonaceous fuels is an essential step to which all nations will have to come. I applaud the current move towards conservation and demand management. Without doubt it can do a great deal. But I do not believe that successor generations will agree to do without cheap, abundant, reliable electric power; and conservation will not achieve that for long. I see no source that can provide substantial accretions to supply, other than nuclear power. And I am almost sure – no sensible person is ever certain – that we can render the harnessing of that power cheaper and safer than it already is.

The great threat is now, as it has been ever since the first artificial fission, that nuclear technology will be put to nefarious use. The breakdown of the Soviet Union has posed entirely new and menacing threats; large arsenals of nuclear warheads awaiting disposal; small armies of nuclear technicians thrown out of their jobs, and eager to work for anyone who can pay; various irresponsible governments and trigger-happy leaders; and petty nationalisms striving to turn back what I had hoped we had learned, that the unity of the human race is the only sane destination for political effort.

In the U.N.'s effort to contend with this threat, which I consider mortal, the IAEA has played a considerable but insufficient role, and we can be happy that Canadian individuals have contributed to this effort. Our federal government, too, has acted responsibly in support. But much more needs to be done – not least by many of the people present in this room.

All I can suggest in closing is that the Canadian industry soldier on. A decade or so more of smooth, accident-free operation by our reactors – presumably those already built – with capacity factors high enough to keep prices within reach – will do more to disarm the critics than the largest public relations effort. I hope, in ten years time, that my successor at this podium will be able to confirm my prediction.

The only proof of safety is visible freedom from harm; and the only proof of economic viability is a price that the consumer can afford, and that is lower than that of competing sources. These are the challenges to which this Association should dedicate itself.

Calls for Papers

Fourth International Conference on Simulation Methods in Nuclear Engineering

2-4 June 1993, Montreal

Abstract deadline: 30 November 1992

to: A.F. Oliva
Ontario Hydro, H11, D12
700 University Avenue
Toronto, Ontario
M5G 1X6

or: H.M. Huynh
Hydro-Quebec
6600 Cote de Neige, Ste 215
Montreal, Quebec
H3S 2A9

International Conference on Expanded and Rolled Joint Technology

13, 14 September 1993, Toronto

Abstract deadline: 30 November 1992

to: G. Kharshafdjian
AECL-CANDU
2285 Speakman Drive
Mississauga, Ontario
L5K 1B2
Fax: (416) 823-8006

International Nuclear Congress

3-6 October 1993, Toronto

Abstract deadline: 31 December 1992

to: Dr. Ben Rouben
AECL-CANDU
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Mississauga, Ontario
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Darlington Fuel Damage Investigation

W.B. Stewart
(Ontario Hydro)

Ed. Note: *The following paper is drawn from a presentation by the author to the Canadian Electrical Association in September 1992 which, in turn, was based on a paper co-authored by Dr. Stewart and R.G. Lalonde, also of Ontario Hydro, given at the CNA/CNS Annual Conference in Saint John, June 1992.*

Summary

An extensive investigation of the Darlington Fuel Damage problem has been undertaken. Based on fuel inspection results, test programs on Units 1, 2 and 3, and also supporting results from out-reactor laboratory programs and modelling programs, the primary source of fuel bundle end plate cracking and extreme bearing pad wear is considered to be pressure pulsations associated with the blade passing frequency of the Primary Heat Transport (PHT) system pumps, coupled with acoustic resonant amplification of these pulsations within various piping components of the PHT system. The original PHT pump impellers have been replaced to change the blade passing frequency in order to reduce the pressure pulse level and fuel string response.

Introduction

The Darlington Generating Station is a four unit CANDU nuclear station owned and operated by Ontario Hydro. Each unit has a gross electrical valid output of 935 MW(e). Darlington NGS is located at Bowmanville Ontario, 70 km east of Toronto.

A simplified flow diagram is shown in Figure 1. The reactor is a horizontal vessel with 480 axial pressure tubes which contain the nuclear fuel bundles (Figure 2) and heavy water coolant. The heat transport system circulates heavy water through the fuel channels, removing the heat produced by the fuel. The heat is then transferred to natural water in the steam generators.

The Fuel Damage Investigation has focused on two problems: cracked fuel bundle end plates and bearing pad wear/pressure tube fretting.

The problem started on November 30, 1990 with the Unit 2 reactor operating at 100% full power, a routine recycle fuelling operation was attempted on channel N12. However, the fuel carrier containing two irradiated bundles, stalled short of its home position while being advanced into the outlet end fitting. The fuel carrier was positioned with difficulty but fuel could not be pushed into the channel. Although the fuelling operation was aborted, problems were encountered during attempted reinstallation of the shield plug and closure plug. Indications were that there was debris in the outlet end fitting and both the Gaseous Fission Product monitor and heat transport system chemical analysis were indicating damaged fuel in the south loop, the loop containing channel N12. On December 23, 1990 the unit was shutdown to install a maintenance cap on the end fitting. The Unit restarted on January 8, 1991, but ran for only a few days.

Unit 2

Unit 2 fuel load started on June 17, 1989 and First Criticality was achieved on November 5, 1989. Due to problems unrelated to fuel, Full Power was not achieved until July 4, 1990. Unit 2 was operated at high power levels for most of the period from July to November, 1990 until the incident occurred.

On January 12, 1991 the fuel carrier containing the recycled fuel bundles was discharged to the Irradiated Fuel Bay, at which time fragments of fuel elements from the bundle in position 1 of channel N12 were discovered. (Fig. 3) Unit 2 was shut down and an investigation into the cause of the fuel damage was initiated.

The evidence from the fuel fragments (subsequently confirmed) was that part of the N12 position 1 bundle, consisting of some centre and inner ring elements broke free of the bundle and moved through the fuel latch prior to the refuelling attempt.

Subsequent to the shutdown of Unit 2, in-reactor inspections of the downstream end plates of selected bundles in position 1 were performed with CIGAR video camera inspection equipment, which identified a number of crack like indications.

Following the first CIGAR inspection, preparations were made to ship irradiated fuel to AECL's Chalk River Laboratories and Whiteshell Laboratories for examination in hot cells.

The hot cell examinations provided the best characterization of bundle damage, including detailed end plate crack characterization and also bearing pad and spacer pad fretting wear. Observations of visually indicated partial and incipient cracks in the hot cell examinations were influential in directing the early Irradiated Fuel Bay inspections and CIGAR video camera inspections.

Inspection of discharged fuel bundles in the Irradiated Fuel Bay (IFB) is a normal part of fuel performance monitoring. However, following the N12 fuel damage finding, a significantly expanded program of IFB fuel bundle inspections was initiated. The initial focus was to inspect discharged bundles from the first charge of Unit 2 that were available in storage modules in the fuel bay. The available bundles were those from positions 10, 11, 12 and 13 which had been discharged during normal four bundle shift fuelling.

By the end of April 1991, a number of channels with visible end plate cracking indications from CIGAR video camera inspection were defuelled. Inspection provided evidence of extensive fuel string wear and damage in channels

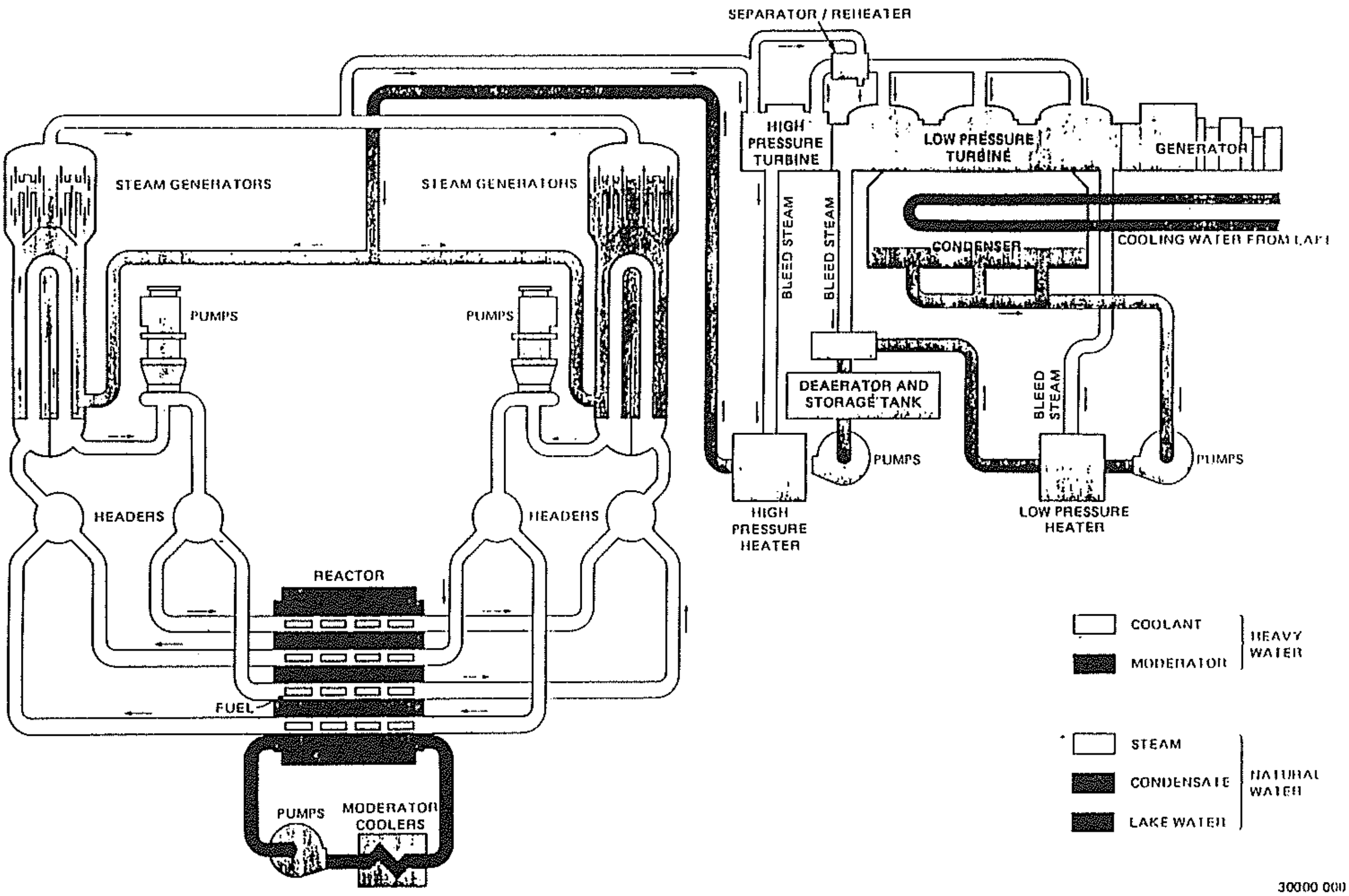

Figure 1: Simplified Unit Flow Diagram

D2K12, D2K13 and D2J13, ranging from multiple cracks in a number of bundle positions, through heavy spacer sleeve interaction wear on outboard bearing pads of bundles in position 13, to varying degrees of inter-element spacer pad and end plate impression wear along the fuel strings.

A data collection program to assist in identifying the cause of fuel damage was undertaken in July 1991. Characterization of damaged fuel in Unit 2 has recently been completed. Endplate cracks have been identified on fuel from 8 channels (J12, J13, K12, K13, M13, N12, Q12 and R13). Severe bundle 13 bearing pad wear, due to interaction of the bearing pad with the spacer sleeve, has been observed on fuel from 7 channels (J13, J14, K07, K12, K13, M12, V20).

CIGAR pressure tube inspection has been performed on 19 channels. Fuel Channel K13 was replaced due to a 0.5 mm deep fret mark, as well as a desire to physically examine fuel channel components. Recently, the entire assembly was sent to CRL for characterization.

The CIGAR inspections did not identify any other pressure tube that has to be replaced, although channel N12 was changed due to fuel debris in the end fitting liner.

At the time of writing of this paper it is planned to restart Unit 2 in early September 1992.

Unit 1

Unit 1 fuel load started on August 1, 1990 and first criticality was achieved on October 29, 1990. Full Power operation was achieved January 12, 1991 and continued until March 9, 1991 when the unit was shutdown for a planned maintenance outage. AECB approval to restart the unit was not secured until August 10, 1991 due primarily to concerns over the fuel damage found in Unit 2. As part of the Unit 1 restart an extensive data collection program, similar to that undertaken on Unit 2, was undertaken. The unit operated from early September 1991 to October 17, 1991 when another planned maintenance outage started. An extensive fuel inspection program during this period of operation did not identify any significant fuel damage. AECB approval to restart the unit was obtained December 24, 1991 and the unit operated until January 26, 1992 when heat transport revised (and more restrictive) Iodine levels exceeded the shutdown limits. The Iodine excursion was later found to be due to debris fretting wear of fuel elements and was not associated with endplate cracking or excessive bearing pad wear. Subsequent to the shutdown, an endplate crack was identified during IFB inspection of a bundle from channel M13. As well, significant bearing wear was observed on fuel discharged from two channels (H13 and K18). It was concluded that the same mechanism which caused the damage on Unit 2 was present on Unit 1, and the decision was made not to restart the unit until a design solution was installed. New pump impellers were installed and the unit reconnected to the grid on July 14, 1992.

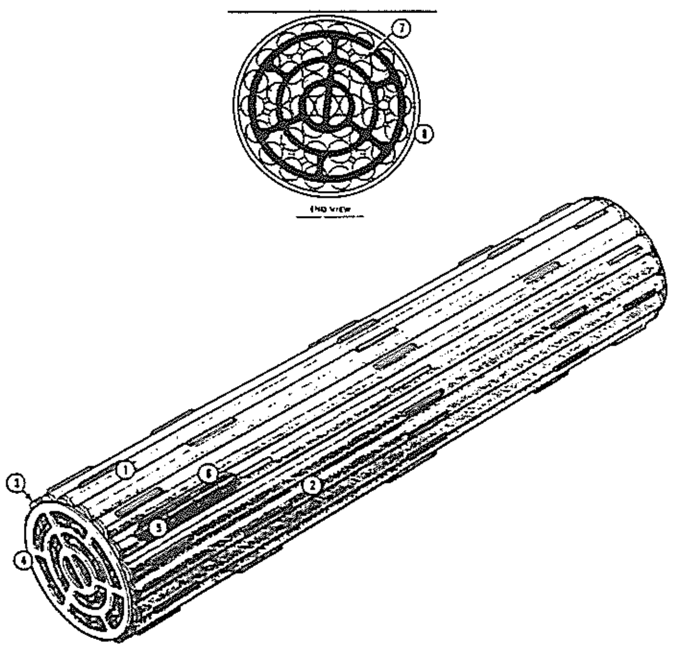

Figure 2: Fuel Bundle

Organization

Following the identification of fuel fragments from channel N12, an investigation team was established. The objectives of the team were to determine the cause of the N12 failure, and also to determine the implications for continued operation of Unit 1 and Unit 2 return-to-service. Weekly Technical review meetings were held starting in late January 1991. In March 1991, a Vice Presidential level Steering Committee was established.

The structure and membership of the investigation team has evolved as the scope of activities has changed. At the present time, over two hundred staff from Ontario Hydro, AECL and other organizations are involved in the investigation.

The initial activities of the investigation team were concentrated on evaluating potential scenarios whereby the observed break-up of the N12 bundle in position 1 could have occurred, assessing the potential implications of bundle break-up occurring in-reactor, establishing a fuel inspection plan and reviewing operating history. The work was focused in large measure on identifying the causes of fuel damage observed in Unit 2 as shown in Figure 4.The first scenarios addressed involved possible fuel manufacturing defects, excessive force during manual loading of the first charge fuel, debris fretting damage to the end plate, and possible mechanical overload of the bundle by overextension of the fuelling machine ram during the N12 fuelling operation. With very limited information available, the most logical scenarios were ones involving mechanical overload induced ductile failure mechanisms which could damage the position 1 bundle.

In parallel, tests were initiated in the flow visualization rig at the AECL Sheridan Park Engineering Laboratory (SPEL) to investigate the vibration behaviour of loose elements in a downstream bundle and possible vibration induced fretting of the pressure tube. There was a suspicion that low cycle/high amplitude fatigue was the mechanism that had caused the break-up of the D2N12/1 bundle, based on preliminary results of detailed examination of an endplate fragment from D2-N12/1 at Chalk River Laboratories. A series of tests were performed in the SPEL flow visualization rig with pumps cycle on and off. However, these tests did not produce any end plate cracks, which indicated that low cycle/high amplitude fatigue was a doubtful mechanism to cause the observed damage.

On Unit 1 in March 1991, a series of vibroacoustic endfitting vibration and pressure pulsation measurements were taken and these measurements indicated pulsations and vibrations at the 150 Hz vane-passing frequency of the pumps,

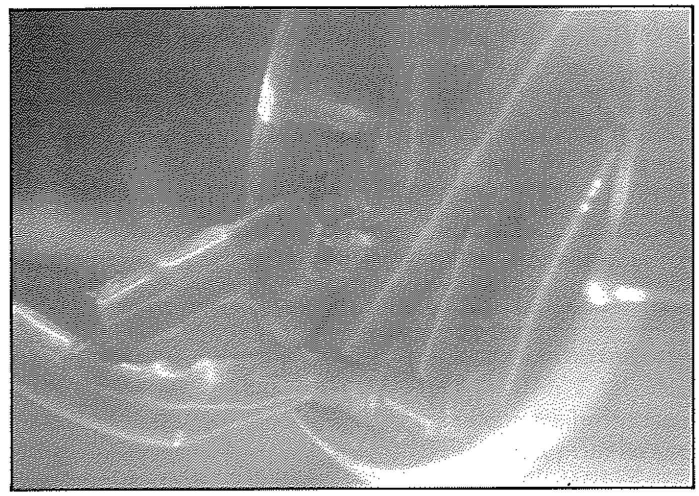

Figure 3: Fragments of loose fuel bundle elements in channel

as well as components at 30 Hz and in the 6-12 Hz range. Since the pressure measurements were taken at the end of long instrument lines, the 6-12 Hz components were most probably associated with instrument line resonances excited by broad-band turbulent eddies in the flow. Conflicting views existed regarding the significance of the higher frequency pressure pulsations and vibrations, resulting in a wide range of varying hypothesis being formulated in the ensuing months. As part of the effort to resolve issues pertaining to possible fuel damage mechanisms, testing on Unit 2 was performed in July 1991, and on unit 1 during the August, 1991 restart. Hydraulic, fuel bundle and fuel string modelling and analysis were also initiated in this time period.

During the period from April to early June 1991, a wide range of analysis and testing activities were focused around possible low cycle fatigue mechanisms: large amplitude flow variations due to pump starting and stopping, flow variations due to boiling at channel exits, static bundle overload due to excessive hydraulic drag load, flashing and waterhammer pressure surges in the ROH balance lines and pressure surges associated with pump startup. These areas were pursued, in part, because of observations from the operating history of Unit 2 and, in part, from the postulation that cracks could have been initiated by some event, or series of events, which had stressed end plates severely, leaving the endplates susceptible to crack growth and propagation due to lower amplitude cyclic loads.

Metallurgical Investigation

In the first half of 1991, the metallurgical investigation included a number of review and testing programs related to establishing fuel bundle and materials properties. The properties of the welds between the fuel element end caps and the end plate were reviewed and tensile strength of the welds were tested for GE (Canada) and Zircatec fuel (both GEC and Zircatec provide fuel for Darlington. The specifications used are identical but there are slight differences in manufacturing technique). A series of small specimen and bundle fatigue tests were initiated to establish fatigue failure criteria under different loading conditions and temperatures. In addition, corrosion fatigue and possible contribution of delayed hydride cracking was investigated. The early fatigue life testing generated data regarding low cycle fatigue, driven mainly by the need to quantitatively assess the postulated low cycle fatigue failure mechanisms. Subsequently, the emphasis turned to high cycle low amplitude fatigue, as information was acquired from the Chalk River Laboratories hot cell examinations of end plate cracks.

In the summer of 1991, information was being generated from the metallurgy investigation regarding the interpretation of deuterium pickup and oxide thickness measurements from fuel bundle end plates, interelement spacers and bearing pads. These measurements were being used to infer information whether wear was ongoing or had started and stopped; whether wear had occurred under hot or cold heat transport conditions; and to estimate the time at which end plates had cracked. Attempts to use deuterium pickup measurements as indicators of wear at hot or cold conditions proved fruitless, and by November 1991, a consensus was reached that the measurements could not be used to draw any conclusions in this regard. However, work on interpreting oxide thickness measurements for inferring some wear characteristics and for crack dating has been ongoing since July 1991. Additional studies and reviews were undertaken to assist in quantifying wear rates on spacer and bearing pads and to identify areas of uncertainty in interpretation of observed wear characteristics. This information was of importance in terms of identifying possible conditions under which accelerated wear may have occurred and to differentiate ongoing wear from transient wear.

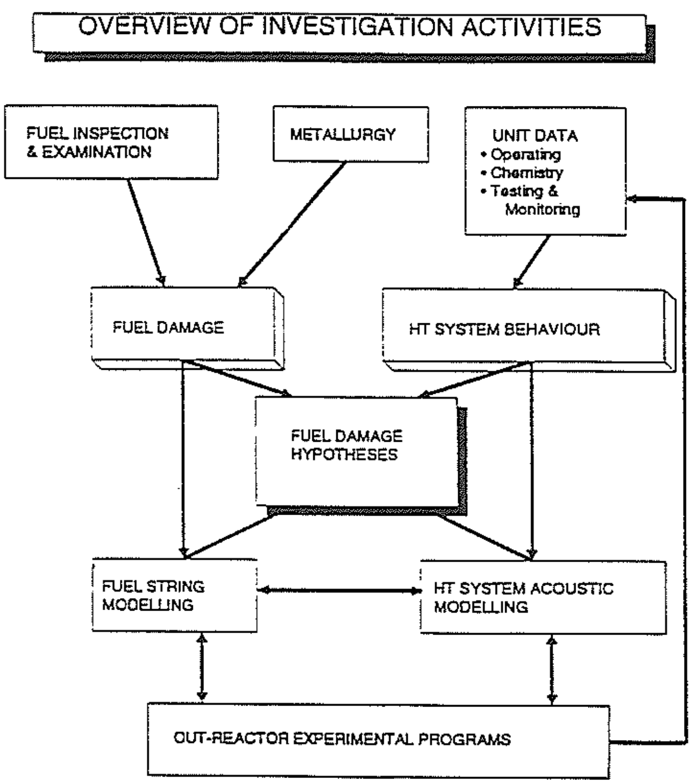

Figure 4

Metallurgical examination of endplate cracks established that the cracks are due to the result of low amplitude, high cycle fatigue with alternating stress levels just above the fatigue limit.

Loop Testing

By June 1991, with high cycle fatigue failure being confirmed as the primary mechanism for end plate cracking, and the extent of string damage in some Unit 2 channels, such as K12, Q12, K13, J12 and J13, evident from IFB inspection, the need for out-reactor loop testing of 13 bundle fuel strings became apparent. The early testing in the flow visualization rig at SPEL was geared primarily to the effects of hydraulic drag loads on the position 1 fuel bundle under steady flow conditions and large amplitude cycling over a range of flow rates. The results did not indicate any of the failure modes seen in-reactor. Loop testing was initiated at Stern Laboratories and SPEL to address vibration and wear behaviour under a range of hydraulic conditions. The direction of the loop testing program was significantly influenced by the Unit 2 testing program performed in July, 1991 noted earlier. In October 1991, loop testing was also initiated at General Electric (Canada) in their Darlington fuelling machine test facility.

The Unit 2 measurements of pressure pulsation and end-fitting vibrations at 150 Hz, as well as flow variation measurements from the Reactor Regulating System (RRS), Fully Instrumented Channels (FINCH) and the Shutdown System (SDS), 1 and 2 safety instrumented channels were employed to direct some parts of the loop testing program. The objective was to establish the behaviour and sensitivity of fuel response to flow and pressure variations similar to those observed in reactor. By quantifying fuel response to the range of hydraulic conditions, a more definitive identification of dominant mechanisms was sought.

Another series of tests, performed on the Bruce channel in the Nuclear Process Components Test Facility at Ontario Hydro's Research Division, was geared to investigating the response of fuel strings to external mechanical vibration of the end-fittings. This program involved both radial end fitting vibration and axial vibration of the fuel string.

Additionally, a number of tests have been performed in the different loop facilities to support analysis and interpretation of test data from Units 1 and 2, as well as to assist in establishing suitable monitoring criteria for Unit 1. These tests include characterization of the frequency response of instrument lines and determination of fuelling machine transfer functions (gain and phase at fixed frequencies as a function of coolant temperature) to assist in interpreting pressure measurements obtained from transducers installed in fuelling machine heads.

Some of the loop tests at Stern Laboratories and SPEL were geared to supporting analytical modelling of hydraulic acoustic phenomena in the heat transport system. This work has included tests to determine sonic velocities in fuel channels and feeders, and tests to identify and measure fluid dynamic acoustic behaviour in feeders and fuel channels. In addition, tests were conducted to measure such parameters as fuel bundle and fuel string stiffness, which were of importance to modelling of fuel string behaviour.

The recent focus of the out-reactor test loop program has been to investigate the bearing pad wear rates at pulsation levels measured with 7 vane impellers on Unit 3.

Acoustic Modelling

The acoustic pressure pulsations observed in unit test data initiated hydraulic modelling and analysis activities aimed at determining whether the pressure pulsations originating at the HT pumps are a significant contributor to the fuel damage. In addition, design modifications to reduce or eliminate the acoustic resonance behaviour were under consideration from the early stages of the investigation, and acoustic analysis was required to assess proposed options.

Initially two computer codes, ABAQUS and a proprietary code of Engineering Dynamics Incorporated (EDI), of San Antonio, Texas, a consultant retained by Ontario Hydro, were used to perform this analysis.

Later in 1991 a computer code, WHAM, recently developed by Ontario Hydro for assessment of waterhammer related consequences of pressure tube failure, was modified and also applied to this analysis. This code has the capability to handle both mass transport related hydraulic flow behaviour, as well as acoustically propagating hydraulic behaviour.

Experimental studies in support of the acoustic analysis work are being conducted at OHRD Nuclear Process Components Test Facility (NPCTF) and the University of Toronto Institute for Aerospace Studies (UTIAS). At the NPCTF, the Darlington HT Pump Test Loop is used to characterize the Darlington HT Pump. Attached to the same loop, a small scale model Darlington HT RIH/feeder arrangement is used to evaluate proposed design solutions. At the UTIAS, a similar model using air rather than water as the fluid medium is being developed for the same purpose.

Fuel Bundle and Fuel String Modelling

The IFB inspection program which involved regular examination of Unit 1 bundles discharged from positions 1, 2, 12 and 13, using a modified four bundles push scheme, was not indicating any significant wear or damage similar to that observed in Unit 2. These observations raised questions regarding the source of differences between the two units. In attempting to generate answers, additional analytical work was initiated related to fuel bundle and string modelling and factors that may affect fuel bundle and string response experiencing variations of hydraulic loading.

The objectives of this analytical modelling work are to develop structural models of a fuel bundle and the fuel string, and to determine the important parameters that govern the in-reactor fuel response. It is of particular interest to determine whether mechanical resonances of the fuel bundle or fuel string are involved as contributing conditions to fuel damage in Units 1 and 2. The results of the analysis have been used to compare the predicted fuel damage patterns to the observed in-reactor damage patterns.

In addition, a number of experimental activities were initiated to generate data to quantify key parameters in the analysis models. This experimental work includes tests to establish the vibration behaviour of bundles, stiffness components of unirradiated fuel bundles, stiffness of UO_2 pellets, and vibration characteristics of a string of thirteen bundles.

Damage Hypothesis

In the course of the investigation a large number of potential fuel damage mechanisms have been postulated and evaluated. It should be noted that in the early stages of the investigation when there were few available facts, the postulated mechanisms covered a very wide range of possibilities. Subsequently, a number of these have been firmly established as being not relevant.

The damage mechanism believed to have caused the majority of damage observed in Darlington is pressure pulsations at 150 Hz in the PHT system.

This mechanism involves amplification of pressure pulses originating from the primary heat transport pumps as the impeller vanes pass the pump cutwaters.

The pulses, which occur at the 150 Hz vane passing frequency, are amplified by acoustic resonance, in the pump discharge piping, reactor inlet header or inlet feeders.

In addition, varying degrees of either attenuation or amplification of the pressure pulses will occur in individual channels. The response in individual channels is determined by such factors as inlet and outlet feeder lengths and coolant temperature (which determines the local sonic velocity). The closer a particular channel is to a resonance at 150 Hz, the more likely it is to exhibit amplification of pressure waves. The net effect is that combined travelling wave/standing wave pressure pulsations occur in fuel channels, with magnitudes governed by location of feeder connections on inlet headers and the feeder/channel response characteristics.

The fuel string response to pressure pulsing can depend on the axial alignment of any standing wave with the fuel string itself and with the proximity to 150 Hz of a natural frequency of the fuel string.

Unirradiated fuel strings tested at cold conditions, indicate that the response falls off above 140 Hz, suggesting a fuelstring resonance at or below 140 Hz. This is consistent with fuel string modelling which predicts a fifth mode natural frequency at 130 Hz. The natural frequency increases with temperature and power and is affected by time at temperature and by irradiation, so that the tuning of the fuel string to 150 Hz is possible at some point in time.

In addition to fuel element stiffness effects, creep of the endplates under the combined effects of hydraulic drag loading and irradiation can influence the fuel string through load shedding. This factor could be involved in causing high end plate stresses in channel outlet bundles, which would result in a progressive extent of damage up the channel as seen in some Unit 2 channels. It would also be expected to occur more readily in Unit 2 due to the fuel loading pattern differences between the units, which resulted in more GE Canada fuel in the central region of the core in Unit 2. Unit 1, on the other hand, had predominantly Zircatec fuel in the centre of the core, which is likely to load shed to a lesser extent because the end plates were more concave.

Potential Solutions

In parallel with the investigation into the causes of fuel damage in Unit 2, a number of activities were initiated to assess and design potential solutions that would mitigate the effects of the 150 Hz pressure pulses from the pump. These activities were premised on the basis that the 150 Hz pulsations were the primary cause of the fuel damage. The possible solutions considered were:

1. Replace the existing 5 vane pump impeller with a 6 or 7 vane impeller to change the vane passing frequency of the pressure pulses from 150 Hz to 180 Hz or 210 Hz, respectively. The replacement of the 5 vane impeller with 7 vane impellers was scheduled and new impellers have been procured and installed.
2. Add an acoustic filter with a volume-choke-volume arrangement to the piping between the HT pump and the RIH to reduce the amplitude of the 150 Hz pressure pulses entering the header. This device acts as a low pass filter that attenuates incoming pressure pulsations above a threshold value.
3. Introduce active cancellation of the out-of-phase pulses that are produced at each pump cutwater such that the amplitude will be attenuated before reaching the header. In an ideal situation, perfect cancellation would result in absolutely no pressure pulses downstream of the cancellation point.
4. A number of smaller scale piping modifications based on principles of acoustic filtering, detuning the 150 Hz frequency from the pump or partial active cancellation were considered.
5. Detune the mechanical resonance occurring at 150 Hz within the pump discharge lines and the RIH. The header vibration is predicted to amplify the pressure pulses in the header.
6. Add a fuel supporting shield plug (FSSP) to the outlet end to support the central region of the outlet bundles, minimize fuel string axial motion and thus minimize the alternating stress component. This option would be primarily a solution to end plate cracking since out-reactor tests have shown that it is not effective in eliminating axial motion of the inlet bundle.
7. Reduce the flow rate in fuel channels, by trimming the impeller or adding a flow restrictor, to the design level or a lower value. The intent of this modification is to reduce the main stress level in the endplates and thereby, alleviate the endplate cracking problem. Based on Unit 1 inspection results, this option is not effective in eliminating inlet bundle wear.
8. Modify the inlet shield plug to produce a more streamlined flow into the channel and minimize the bundle rocking as a potential contributor to inlet bundle wear.

   Testing is underway to identify the optimum inlet shield plug configuration. Preliminary test data shows that inlet bundle motion can be reduced by a factor of 2-3.

Unit 3

In the Spring and Summer of 1992, an extensive test program was undertaken on Unit 3 with the following objectives:

1. Perform a complete characterization of 150 Hz pressure pulsations at different parts of the PHT system and determine the input/response behaviour throughout the system.
2. Identify the mechanisms and the extent to which flow oscillations, mechanical vibrations and fluid/structure interactions contribute to fuel string dynamics and associated damage.
3. Re-characterize the PHT system at 210 Hz to determine the effectiveness of 7 vane impellers in reducing pressure pulses, flow and/or mechanical excitation of the fuel string.

The program has been completed and the major conclusions are:

1. At Zero Power Hot conditions, the outlet bundle end plate deflections are reduced by an order of magnitude by changing from 5 to 7 vane impellers.
2. At Zero Power Hot conditions, the inlet bundle axial motions are reduced by an order of magnitude by changing from 5 to 7 vane impellers.
3. At Zero Power Hot conditions, the inlet bundle transverse motions are reduced by a factor of 2 by changing from 5 to 7 vane impellers.
4. There is no dominant frequency component that can be identified as the major contributor to residual bearing pad wear. Additional out-reactor tests will be required to assess the relevance of the low level/low frequency axial and transverse bundle motion to bearing pad wear.

CONCLUSION

An intensive, wide-ranging investigation into the causes of the Darlington fuel damage has been underway since the occurrence of the N12 event on Unit 2. (Fig. 5) Although this investigation has not yet concluded, a number of definitive statements regarding the fuel damage can be made.

Endplate cracking is due to high cycle fatigue occurring at amplitudes just above the fatigue limit. The cracking of fuel bundles appears to have occurred at distinct periods in time and the cracks have developed over a relatively short time periods.

Endplate fretting wear occurs down the fuel string with a high incidence of impression wear occurring at the downstream bundles and at bundle position 9 on Unit 2, while Unit 1 indicates a high incidence at bundle positions 8, 9 and 10. The incidence of wear at bundle positions 12 and 13 is low on both units. This, together with hot cell examination of some wear marks, indicates a predominant relative axial movement along the fuel string. This is also consistent

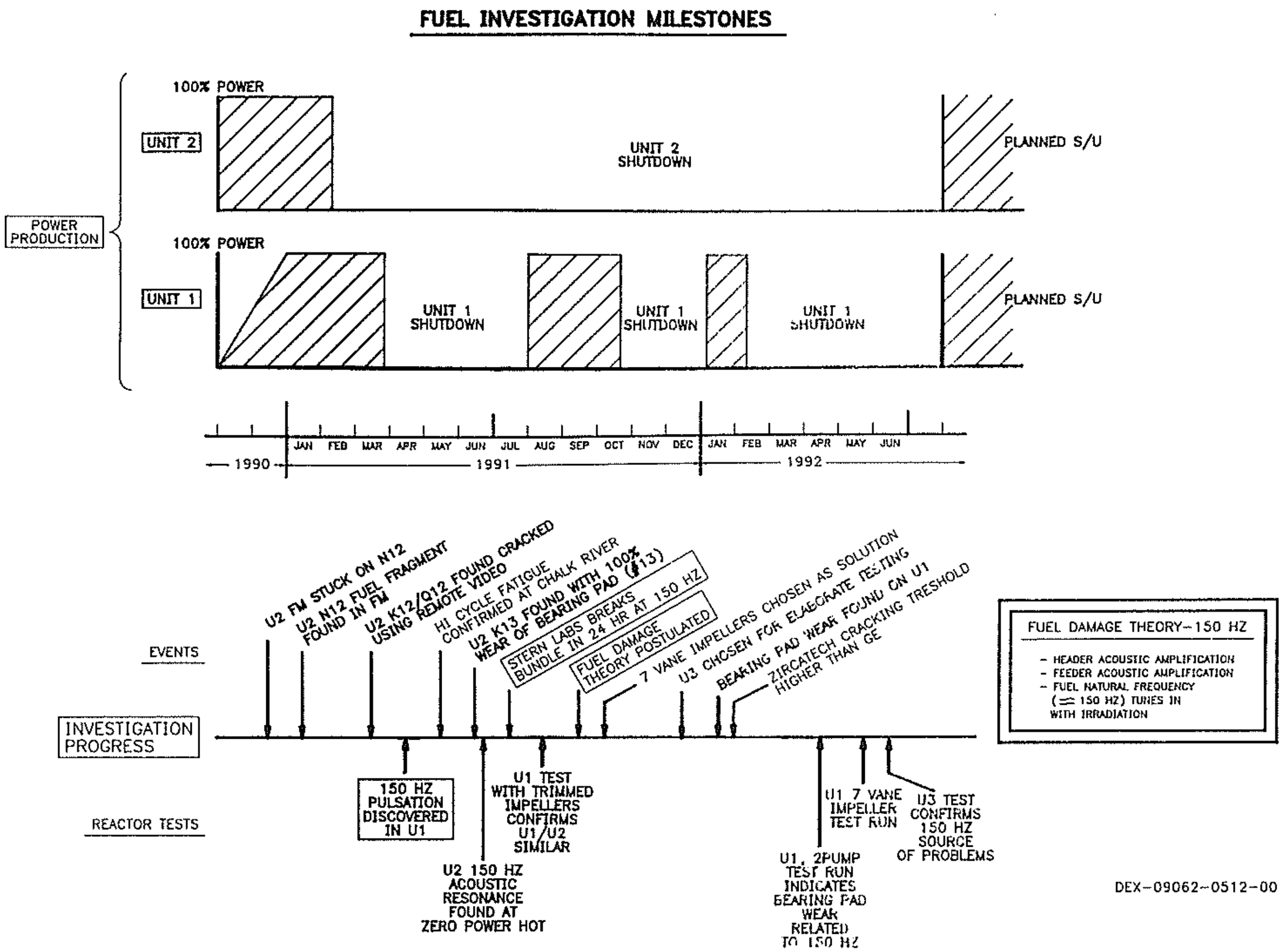

Figure 5: Fuel Investigation Milestones

with spacer pad wear, particularly between rings of elements. In addition, the pressure tube fretting wear on channel D2K12 is consistent with the higher impression wear of endplates in the region of the position 8, 9 and 10 bundles.

The spacer sleeve interaction wear of outboard bearing pads shows evidence of axial wear movement, as inferred from fret marks on the bearing pads and the dimensions of the pressure tube fret marks. However, the possibility of channel inlet flow contributing to bundle 13 bearing pad wear remains open. No definitive conclusion has been reached regarding the mechanism, or mechanisms causing bearing pad wear.

The clearly established 150 Hz resonances in the reactor inlet headers and inlet feeders at hot conditions, together with the indications of a significant number of Unit 2 channels with damage exhibiting good acoustic transmission response, has contributed to this being considered the dominant mechanism causing fuel failure. Practical design solutions have been developed to significantly reduce the amplitude of the pressure pulsations and reduce the heat transport system sensitivity to resonant conditions. These are expected to significantly reduce the potential for incurring further fuel damage.

Acknowledgement: *The author would like to thank J.C. Luxat who coordinated the preparation of the "Report on the Investigation to Fuel Damage Causes Following the Unit 2 N12 Event" from which the majority of this paper was taken.*

An Overview of the Metallurgical Investigations into the Failure of Darlington NGS Unit 2 Fuel Bundle End Plates

by E.G. Price
(AECL-CANDU)

1.0 Introduction

In November 1990, difficulty was experienced in refuelling channel N12 of DNGS Unit 2. The carrier tube containing replacement fuel (from another channel) could be inserted into the outlet end fitting with difficulty but fuelling could not be performed. The carrier tube was removed from the end fitting but in turn difficulties with the fuelling machine operation indicated fuel debris was trapped in the fuelling machine. When the carrier tube was fully removed from the fuelling machine at a later date and the fuel from the carrier tube examined in the fuel bay, pieces of fuel elements were found among the intact replacement fuel. This finding led to the formation of an investigation team to determine the cause of the problem. The team which subsequently recommended an examination by television of the downstream end plates on outlet bundles of a number of channels. This inspection revealed other channels in columns 12 and 13 (either side of the midline of the reactor) in which the outlet bundle had cracked end plates. A typical diagram of cracking sketched from the video of the inspection is shown in Figure 1.

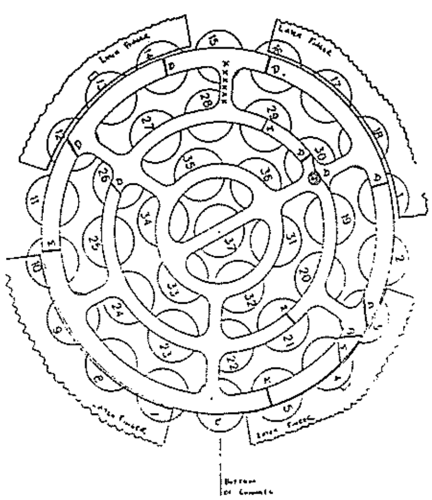

Figure 1: Diagram of a Cracked Outlet Bundle End Plate (Channel K12) Obtained from an In-Situ Television Inspection

Following the detection of cracking a metallurgical committee was set up to support the activities of the N12 team. The nominal objectives of the committee were to determine:

- the mode of failure of the end plates
- when failure had occurred
- the type of stressing or metallurgical conditions that caused failure
- the heat transport conditions under which the cracks were formed

This overview describes the examination and test effort into damage cause. It involves the efforts of inspection teams at Darlington site, support fuel engineering at Ontario Hydro NOCSD, examination teams at the Chalk River and Whiteshell Laboratories of Atomic Energy of Canada Limited (AECL) and test efforts at Ontario Hydro Research Department, and AECL-CANDU.

It should be noted that initially the investigation had been concerned with end plate cracking. However as more information on fuel bundle condition was obtained it was apparent that other types of fuel damage existed as follows:

- end plate deformation (doming, dishing or distortion)
- end plate fretting wear
- spacer bar wear
- bearing pad wear (which could indicate pressure tube wear).

Of these, end plate doming and dishing had been observed in fuel exposed in Bruce reactors; spacer pad wear and bearing pad wear had been seen but not of the same magnitude; and end plate fretting wear was just detectable on Bruce bundles following further close examination.

2. The Fuel Bundle and the Fuel String Environment

A typical Darlington fuel bundle is shown in Figure 2. This bundle design has flat shoulders on the end caps to accommodate the outlet end holding latch and a staggered bearing pad arrangement on alternate outer elements. The element end caps are welded to the end plate in a slightly non-symmetrical pattern which differs from manufacturer to manufacturer.

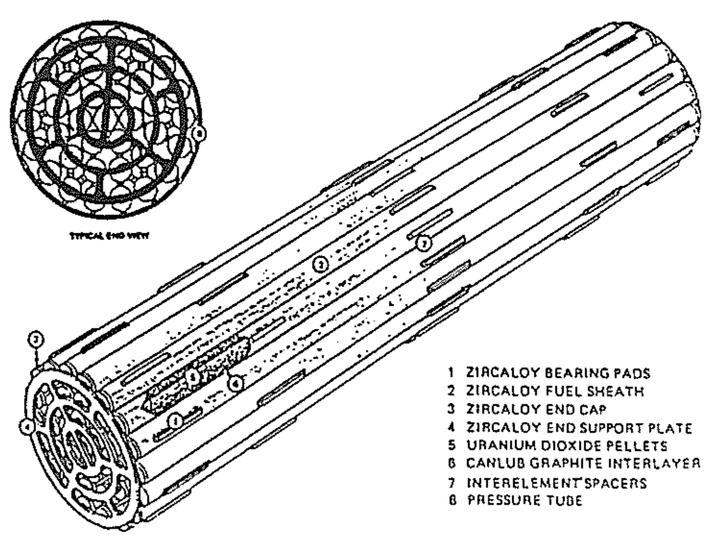

Figure 2: Darlington Fuel Bundle

The weld between the end plate and end cap is really a high temperature diffusion bond induced by resistance heating under pressure. The weld region is slightly stronger than the parent metal. It consists of a core of recrystallized grains that have been heated into and cooled rapidly from the beta grain region and transformed to alpha. From the core region the prior beta grain size gradually decreases to a zone of recrystallized alpha grains which effectively outline the weld zone (Figure 3).

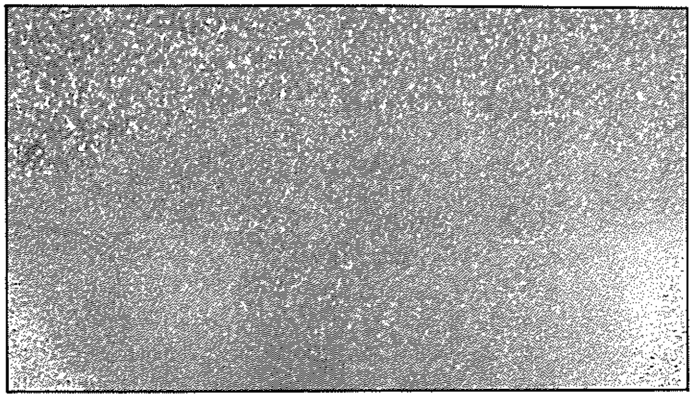

Figure 3: The Weld Microstructural Characteristics of an End Plate to End Cap Weld

The Darlington channel is similar to Bruce B and contains 13 bundles (Figure 4). These bundles are supported by a 4-piece latch which bears on the shoulders of the end caps of the outlet bundle. Depending on the orientation of the bundle two or four elements will not be supported directly by the latch. The outboard bearing pad of the inlet end bundle is supported on a spacer ring between the pressure tube and the liner tube.

The axial load on the fuel imparted by the flow is carried by the latch. The inner element loads are transmitted through the end plates to the outer elements which will carry a load which increases from inlet to outlet end. With high temperature operation, creep deflection of the end plates can lead to contact between the central regions of the adjacent end plates and this will increase the load on the central region of the downstream end plates (load "shedding").

It is obvious that the latch loading of the outer elements and the dished geometry of the bundles allows the inner elements to move axially with respect to the outer from axially varying forces restrained by the end plates.

3. Preliminary Investigations

Due to fuelling machine problems, the observed damaged fuel could not be examined for some time and the videos of outlet end plates were the only inspection information available. An initial series of programs were started that investigated the potential for failure from one or more of the following causes or mechanisms:

- cracking due to initial (manual) fuel loading procedures
- cracking due to zirconium hydride phenomena (delayed hydride cracking)
- manufacturing problems
- accelerated corrosion in the crevice of the end cap to end plate weld
- embrittlement due to hydrogen or nitrogen or other elements
- fatigue due to end plate cyclic deflection from load cycles induced by start-up and shut-down cycles

3.1 Manual Fuel Load Practice

First charge fuel bundles are inserted through the inlet end and slide along the pressure tube on a stainless steel shim until they contact the latch or the preceding bundle. It was surmised that the #1 fuel bundle may at times have hit the latch with sufficient force that the inertia of the inner elements may not have been absorbed by elastic deformation of the end plates and cracking resulted. Attempts to produce such cracking in test channels at site and in channels at Sheridan Park Engineering Laboratories did not reproduce the cracking. Specimen tests on end plate to end cap welds showed that at impact energies greater than could be experienced on impacting the latch, cracking that could be produced was in the form of shallow ductile tears without the characteristics of the end plate cracking.

3.2 Delayed Hydride Cracking

Delayed hydride cracking (d.h.c.) is a phenomenon seen in Zr-2.5% Nb pressure tubes but only rarely in the more ductile Zircaloys used for fuel components. In Zircaloy, d.h.c. can be produced in the laboratory but not as easily as with the higher strength Zr-2.5% Nb alloy. The conditions to cause it are a hydrogen concentration in the metal in excess of the terminal solid solubility; a stress intensity in excess of a threshold value, and an incubation time. Although the fuel had been fabricated about three years before use, an evaluation of the potential for d.h.c. concluded that the conditions were unlikely to have caused cracking and any cracking at room temperature, due to the low velocity of d.h.c. at room temperature, would progress extremely slowly. On heating, the available hydrogen would go into solution and cracking would stop for this reason.

No d.h.c. testing program was initiating because of this conclusion.

3.3 Embrittlement

The video indicated low ductility cracking had developed in the end plates close to weld positions. The possibility of hydrogen, nitrogen and oxygen causing such embrittlement was investigated by chemical analyses and microstructural examination of fuel fabricated over the same time period as the failed fuel. No out-of-specification analyses were observed and metallographic examination failed to show any evidence of hydride or other element segregation. Oxidation in the weld notch was not great enough to cause embrittlement. Subsequently specimens of end cap to end plate welds were hydrided to confirm that the pattern of hydride precipitation was not such as to produce a zone of weakness either side of the weld in the end plate which may have been produced by residual stresses from welding.

3.4 Manufacturing

The fabrication process at the manufacturer of the majority of the failed fuel, G.E. Canada, was reviewed in detail without finding any aspects of the weld procedure that could lead to cracking. The assembly procedure met the requirements of the drawing, specification and approved procedures. However, it was subsequently established that within the drawing tolerances, the amount of dishing of the end plate was greater in one manufacturer than the others, and these differences affect the crept dimensions of the end plate in service and likely the vibration characteristics of the fuel string.

3.5 Fatigue

A fatigue program was started to evaluate the effect of a significant number of start-up and shut-down cycles incurred during commissioning of Unit 2. The pattern of cracking seen in K12 suggested that the location of the latch could have an influence on the stressing pattern on the outlet end plate.

The initial program showed that the number of shutdown/start-up cycles needed to cause failure by low cycle fatigue was much greater than those experienced. Loop tests simulating the startup/shutdown cycles produced the same result. This program then went on to develop the design criteria for fatigue failure of the end cap to end plate welds.

4. Fracture Characterization

Examinations of outlet end bundles at CRL, starting with pieces of the end plate of the N12 channel and continuing with failed bundles from the Q12 and K12 channels, showed that failure had occurred by fatigue. The fracture stresses were generally characterized by a region of relatively featureless crack propagation (called a "black eye" from the SEM photographic image) followed by a region which contained "beachmarks" where the texture of the surface differed but the main crack propagation features were continuous through to adjacent bands (Figure 5). Over this region of surface, fatigue striations 0.5-2.0 microns were present. On some surfaces, particularly those of Q12, up to three crack arrest marks were seen indicating the driving force decreased below the fatigue threshold for a period at that stage of cracking.

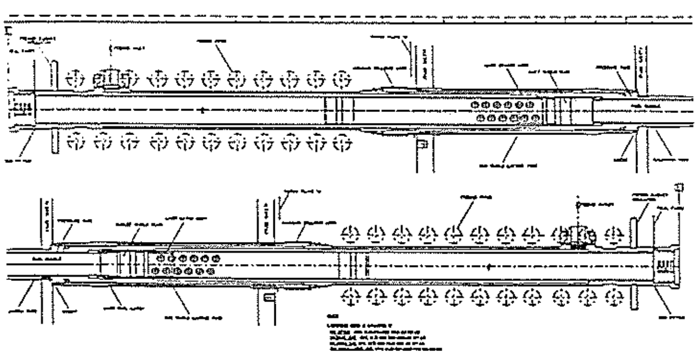

Figure 4: Illustration of Fuel String Positioning in a Darlington Channel

The cracks mostly originated in the crevice formed between the end cap and the end plate by the welding. Crack initiation occurred slightly away from the trip of the crevice at the edge of the altered metal structure and progressed through the heat affected and weld region to the parent metal and through the plate.

The crack surfaces were relatively undamaged by post fracture rubbing and were covered with a thin oxide (<2 microns).

Four main types of cracks were detected (Figure 6):

- those starting from the fissure of the weld close to the intersection of the radial arm and the intermediate ring.

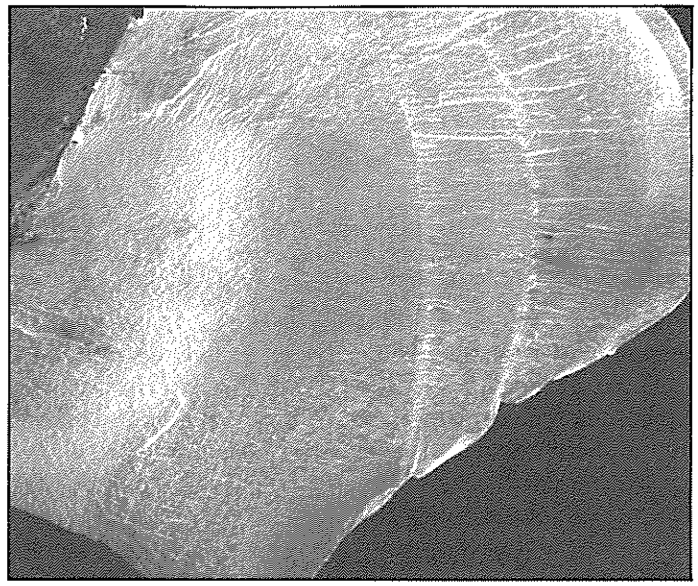

Figure 5: Typical Fracture Surface Formed in the End Plate

These generally produced an "anvil" type crack predominantly through the radial arm. Fracture surface oxide thicknesses were greater on these cracks than on others.

- those from a similar position but where the crack mostly progressed through the circumferential ring giving a "clamshell" appearance to the fracture surface.
- those originating from welds on the circumferential rings which tended to propagate in a radial direction.
- those which did not originate from a weld but from the outside surface and occurred on the radial arms or between pencils on the circumferential rings.

Overall the crack pattern analysis led to the following conclusions:

- practically all the cracks are consistent with stress patterns developed by axial oscillation of the inner pencils with respect to the outer pencils.
- failure occurred first in the region of end plate adjacent to the intersection of the radial and circumferential
- the channels could be divided into two types - heavily damaged channels such as K12 and K13, and lightly damaged channels such as Q12 and N12. In the heavily damaged channels cracks occurred in nearly all areas of the end plate. With bundles from Q12 and N12 failure was predominantly near the intersection of the radial arm and the intermediate circumferential ring on the downstream end plate and on the inner ring of the upstream end plate.
- generally failure occurred as a continuous event.
- the absence of deformation even in the region of the final

ligament indicated a high cyclic stress was not present. The flat fracture surfaces and absence of secondary cracking indicated cyclic stresses were just sufficient to cause cracking.

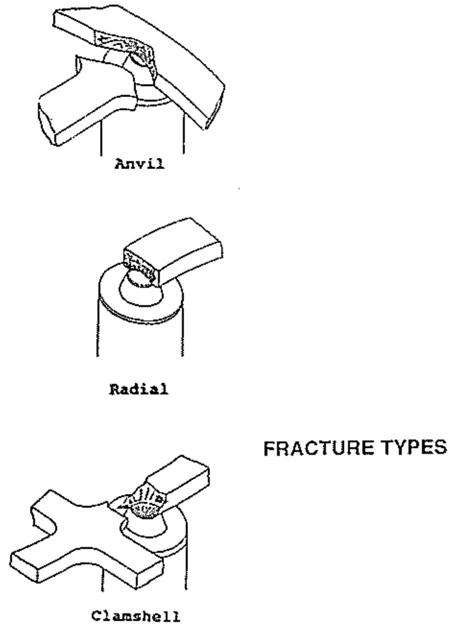

Figure 6: Types of Cracks Observed on the End Plates

5. Supporting Testing Programs

5.1 Fatigue Design Data

As described in another paper,[1] the test program at OHRD was successful in establishing:

- the fatigue strength of the end cap to end plate welds subjected axial loadings. This showed that a fatigue notch reduction factor of 4 was produced by the geometry of the weld, from that produced in unnotched Zircaloy.
- the similarity in features of the fatigue failures indicated that the cyclic stress amplitude was just above the fatigue threshold amplitude. This would imply cyclic life between 4 x 10^5 and 10^7 cycles.
- because of the notch, cracking started early in the cyclic life when the fatigue threshold amplitude was exceeded. At least 90% of the cyclic life was expended in growing a crack to the width of the circumferential ring.
- beachmarks were most easily produced by tests at 310° C in which the cyclic amplitude was slightly changed about a level just above the threshold value.
- the higher the cyclic amplitude the rougher the fracture surface and the greater the amount of associated deformation. Alternatively the closer the cyclic amplitude to the threshold level the flatter the surface.
- fatigue striations became finer than the resolution of the SEM when fatigue life exceeded 4 x 10^5 cycles.
- it was not possible to detect the effect of frequency on crack propagation characteristics above 1 Hz.
- the fatigue properties were similar at RT and 310° C and from manufacturer to manufacturer.

5.2 Other Fatigue Tests

Fatigue tests were carried out on complete fuel bundles on which cyclic axial loads were applied to a bundle loaded against a simulated latch.[2] These tests did not reproduce the cracking in the same location as field failures but the features of crack propagation were similar. They showed that the fatigue life was predictable from specimen tests. It also confirmed the crack growth-cyclic life predictions.

Fuel element transverse vibration was also investigated as a cause of failure by a series of fuel element deflection tests.[2] At lower amplitudes of vibration the fracture appearance was similar to that produced by simulated end plate bending. The fatigue transverse threshold and amplitude was just above the maximum possible amplitude of transverse vibration available to the fuel elements.

5.3 Dating of Fractures

Infra-red spectral reflectance techniques allowed the oxide to be measured at very small thicknesses (<1.5 microns). Using this measurement, the time since cracking was estimated for the out-of-flux end plates of bundles #1 and #13.[3] The ultimate conclusion was that failure occurred after the reactor had reached full power and individual cracks on end plates occurred at intervals after the first crack.

5.4 Fretting Wear

In a number of Darlington channels fretting wear occurred between spacers, between end plates of adjacent bundles and between the bearing pads and the pressure tubes. This fretting was undoubtedly the source of zirconium in the circuit as detected by gamma flux monitors.

The data generated in CRL test programs studying bearing pad to pressure tube wear was made use of to interpret the Darlington fuel and pressure tube damage.[4]

Zirconium fretting wear has the following characteristics when tested in low oxygen water:

(a) large variation in fretting rate under seemingly identical conditions. For example bearing pad to pressure tube wear ratios can vary from 1 to 3 to as high as 3 to 1.

(b) a variable effect of oxide. An initial layer of oxide reduces fretting wear at lower temperatures. The effect was small at higher temperatures (300° C).

(c) a strong dependence of fretting rate on vibration amplitude with amplitudes in excess of 200 microns causing wear rates an order of magnitude higher than amplitudes below 200 microns.

(d) an increase in fretting damage with temperature to about 225° C to 285° C but above 285° C decrease with temperature. About 310° C the rate is about the same as at room temperature.

(e) an effect of water chemistry and the chemicals used to control pH and oxygen content on fretting rate. Using hydrogen as a control chemical produced more fretting wear than LIOH at room temperature.

Fretting wear is dependent on a number of parameters such as wear surface area, A; sliding distances, S; contact force, F_n; wear coefficient K_{FW}; and frequency of motion, F.

The time t_w to wear to a depth D_w is

$$t_W = \frac{A}{2K_{FW} \cdot F_N \cdot f \cdot s} \cdot D_w$$

The time is inversely proportional to contact force, frequency and sliding distance. Thus higher frequencies, longer sliding distances and higher contact forces reduce the time to produce damage. For the same sliding distance, frequencies of 150 Hz, for example, reduce wear times by a factor of 10 compared to 15 Hz.

Using the above relationships and estimated values for the unknown parameters such as wear coefficient it was estimated that the time for observed bearing pad damage to take was days or weeks rather than hours.

For end plate wear the duration of fretting was also estimated to be about 1 month for the worst damage seen.

These estimates suggest that the fretting wear was likely an on-going phenomenon.

Scanning electron microscopy of fretted surfaces showed wear patterns in the form of elliptical marks (dimples) or scratches. The longest dimension indicated the predominant direction of relative motion.

Examination of spacer pads showed that the direction of relative motion depended on bundle position and element location. Spacers separating rings of elements fretted from relative axial motion in bundle #1 (in outline end) or transverse motion (inlet end). Spacers between elements within a ring fretted from relative transverse motion.

Bearing pad wear at the inlet end was predominantly due to relative transverse motion to the pressure tube, but some axially-oriented wear was seen. End plate wear resulted from small relative radial motions of contracting end plates.

5.5 Support to Loop Test Work

Examinations of end plates failed in out-reactor loop tests contributed to the understanding of the fracture process. For instance, correspondence of some of the features of the fractures confirmed the failure temperature as occurring during hot conditions. Generally the loop tests produced failures similar to those seen on the heavily damaged channels in Darlington Unit 2.

6.0 Conclusions

The metallurgical investigations showed that:

(a) Fatigue was the cause of failure.

(b) The cyclic stress amplitude just exceeded the fatigue threshold.

(c) Failure occurred at temperatures at or above 265° C.

(d) Axial cyclic loading of the bundles was the predominant cause of failure. However transverse vibration of the fuel elements may have contributed to the failure process.

(e) Failure predominantly occurred after the reactor had reached fuel power and was not associated with one event, but a series of events in one channel and in different channels.

(f) The uniform oxidation on the surface of field failures indicated crack progression times were not greater than a few days. Correspondence of failure features between in-reactor and out-reactor loop tests indicated 150 Hz oscillations as the prime mechanism of failure.

(g) Fretting damage was more likely an on-going phenomenon. High frequency vibrations will cause higher fretting wear ratios than low frequency vibrations and imply a higher frequency contribution to relative motions between surfaces.

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Ed. Note: *The above paper was presented at the CNA / CNS Annual Conference in Saint John, N.B., in June 1992, and is reprinted here with the kind permission of the author and conference organizers.*

Deadline

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13th Annual Conference

Session Summaries

Ed. Note: Over a hundred technical papers were presented in 16 sessions over the three days of June 8 to 10 at the annual CNS Conference in Saint John, New Brunswick. All were of a high calibre.

To enable those who could not attend to gain some feel of the content of these papers, following are summaries of most of the sessions as prepared by the session chairpersons. On behalf of our readers we thank these dedicated volunteers for these notes. The schedule of papers was printed in the previous issue of the Bulletin, *Vol. 13, No. 2.*

Full proceedings of the conference will be available this fall from the CNS office.)

Session 2: New Concepts and Technology

The first paper "The Concept of a Passive Water-Cooled Tube Reactor without ECC" was given by Won-Pil Baek of the Centre for Advanced Reactor Research, Korea. It deals with a method of using the moderator for emergency cooling. A large tank, containing moderator fluid, is mounted above the reactor, and continuously cooled to maintain the moderator temperature during normal operation. In case of a LOCA there is an ample supply of cold fluid to absorb sensible heat and remove heat by evaporation for many hours. Some new fuel concepts were also described in the paper. The paper generated lively questions, *e.g.* if moderator is heavy water, what is the cost of the D_2O? The concept is still in a very early stage, and many loose ends need to be tied.

The second paper "Design Concepts for Passive Heat Rejection in CANDU Reactors" was given by Jim Beaton of AECL. This paper also favoured the expanded use of passive systems, but took a more gradual approach, recommending a mixture of passive and active systems for a CANDU-6 reactor. A tank on the roof contains light water to be used in a variety of ways for some of the range of malfunctions and accidents envisioned. At least one valve is necessary to initiate the correct use of the water. A steel containment building provides a water jacket to take care of Loss of Coolant ECCS. Here again, many interesting questions came up.

The third paper "Uprating of CANDU Reactors – A Feasibility Study" was given by Khalid Chaudry of AECL. This paper examined the possibility of uprating the Pickering B reactors to produce more power (103% of rated) without major equipment changes. An in-depth safety study showed that there are no safety related impediments, and that uprating to the above extent is feasible. Additional evaluation is required before implementation.

J.E. Hesketh of GEC Alstholm presented the fourth paper "Modern Turbine Generators for Standardized Nuclear Power Plant." The paper addressed the application of standardized NSSS in different parts of the world, in relation to the effects on turbine design of different local parameters such as grid frequencies (60 Hz versus 50 Hz). It examined the problems in designing standardized Balance of Plant for world wide application of the CANDU-3 system, and addressed the performance improvements from "single" as opposed to "double" flow expansion in the cylinder modules.

The fifth paper was substituted for one of the withdrawn papers, and did not appear in the program. This paper, entitled "The Management of Tritium Reduction at Ontario Hydro" was authored and given by Lou Fernandes of Ontario Hydro. It dealt with the tritium reduction program necessitated by the relatively high rate of tritium production in the heavy water in CANDU reactors, particularly in the moderator, and the radiological health effects associated with this. It addressed Containment of TDO, Recovery of escaped TDO, Displacement of tritium from the D_2O systems, and Removal of tritium from the D_2O systems.

The last paper dealt with "D_2O Production by Laser-Induced Selective Multiphoton Decomposition (MPD)" and was given by Michael Ivanco of AECL. This paper examined alternatives to the GS H_2S/H_2O process currently used for D_2O production. The current process is very energy intensive and involves the management of large volumes of H_2S. Possible alternative stand-alone processes are (i) an H_2O/H_2 process which is yet to be developed, and (ii) a laser induced process based on MPD. The paper focused on the development of the laser MPD process, looking at the selection of a suitable working molecule, in which only the deuterated molecules will absorb sufficient energy to decompose at the optimum frequency. The development of the process at CRL is in an advanced state, and a pilot plant could be under construction by 1995. The paper generated considerable interest as evidenced by the many questions from the audience.

Two papers, those on Liquid Shutdown Systems and Advanced Containment, were withdrawn.

– Frank Stern

Session 3: Fuel Behaviour

The session on Fuel Behaviour included four papers concerning fuel behaviour under normal conditions (NOC) and two papers concerning upset conditions. All topics presented related, either directly or indirectly, to fission product release.

The first paper under NOC illustrated very good agreement between theory and measurements of low levels of fission product release into current SLOWPOKE installations from fuel material exposed at a weld joint in the fuel assembly. The next paper confirmed the adequacy of modelling diffusional release of fission products from fuel grains using the Booth model by comparing it to the more exact transport theory solution. Another paper compared ELESIM code predictions to a detailed database for fuel irradiations to extended burnups which showed no enhancement or threshold effect for increased fission product release at the high levels of burnup examined.

Previous studies on CANLUB have depreciated the lubricating quality or barrier effect as the beneficial quality of CANLUB in decreasing fuel failures due to stress corrosion cracking. Data presented in this NOC paper suggests that complex iodine carbon compounds, Zr_xI_yC, utilizing carbon from the CANLUB, can immobilize significant quantities of fission product iodine.

Fuel oxidized in air between 300° C and 900° C produces micron sized particles of U_3O_8. Detailed size distribution studies show a significant effect on particle agglomeration caused by the relative humidity of the oxidizing environment.

Following rapid core heating it is possible for molten Zircaloy to wet and dissolve the UO_2 fuel matrix. Data presented show that the saturation solubility of UO_2 in molten Zircaloy varies directly with temperature and inversely to the oxygen concentration of the melt.

H.E. Sills

Session 4: Reactor Design

Khalid Chaudry presented a paper on the design of feeders for the CANDU-3 reactor. Rick Ricciuti talked about the seismic qualification of equipment modules for the construction of a CANDU-3. Don Burnett explained the advantages of the MkII Slarette tool versus Slar. John Paulisens provided a global view of the proposed CANDU-3 fuel handling system using a distributed control system. Macit Cobanoglu gave a summary of the recent progress realized in LFSCR at the Pickering A reactor. Ray Jaitly provided an overview of CANDU-3 licensing status with emphasis on the PSA studies. Derek Mullin talked about the Point Lepreau Reliability data base for equipment and its uses.

– Paul Lafreniere

Session 6: Safety Analysis 2

There were a total of six papers presented; the only deviation from the original CNS program was the fifth paper of the session. This paper could not be delivered and was replaced by "Development of a Heat Sink Outage Program for Bruce NGS-A," by Rod Cox and Bill Palmer.

Collectively the persons presenting papers in this session represent over one hundred years of experience in the nuclear industry. Topics ranged from mathematical topics, i.e. modelling of reactors and trip parameters and validation of computer codes, to operational topics such as effect of pressure tube failure on calandria tube integrity, new flux detector technologies and development of heat sink programs.

All papers were well presented and well received. The knowledge of the speakers and interest of the audience was superb, making for a very enjoyable session.

– Joel K. Almon

Session 7: Fuel Channel Behaviour

Six papers were presented in this Fuel Channel Behaviour session.

The first speaker, Dr. Lei, illustrated the usefulness of computer codes for the design of the CHAN 28 element High-Temperature Thermal-Chemical Experiment CS28-1. He predicts that due to Zr/H_2O reaction, the maximum fuel bundle surface temperature is reached at a steam flow rate of 8 g/s, the input power being tripped. He also showed that CHAN-II-WL can be used for scoping analysis, whereas CATHENA provides many more details for the final selected cases.

The second speaker, Mr. Sanderson, presented the experimental data and CATHENA simulations of pressure tube circumferential temperature gradients during slow coolant boil-off tests. He pointed out the importance of the methodology used in CATHENA modelling of a sagged pressure tube, on the prediction of experimental results.

The third and fourth papers were presented by Dr. A.P. Muzumdar. In his first presentation, Dr. Muzumdar showed that the computer codes WALLZ5 and Mini-SMARTT-II simulate successfully molten zircaloy/pressure tube contact experiments before rewet of the calandria tube. The rewet transient is quite well predicted by Mini-SMARTT-II, the rewet being not modelled in WALLZ5. In his second presentation, Dr. Muzumdar showed the simulation results of "make-up water" experiments using the computer code Mini-SMARTT-II. Using the thermalhydraulic conditions and the inferred water level transient from the thermocouple measurements as inputs to the code, the simulated pressure tube circumferential temperature profiles show good agreement with experiments.

The author of the fifth paper, Dr. C.H. Borzi, presented a methodology for predicting the positions of the Garter Springs along the axes of the fuel channels in CANDU reactors. Using the experimental knowledge of the positions and their dispersions in the inspected channels, Dr. Borzi showed how to predict the probability of the presence of the Garter Springs and their correlations along the other channels.

The last speaker, Mr. R.G. Moyer, presented the results of Bearing-Pad/Pressure tube rupture experiments and indicated that the new T-pad design appears to have contact conductance values similar to bearing pads currently used on fuel bundles. Mr. Moyer showed that the contact conductance between the bearing pad and the pressure tube was fairly constant throughout heatup and then decreased during the pressure tube ballooning stage.

Pressure tube integrity, especially under LOCA conditions, is an important issue for CANDU reactors. The speakers in this session showed that a good experimental program is in place and computer codes were successfully used for the design and analysis of the experiments. These efforts will certainly contribute to reduce the uncertainties in the predictions of pressure tube behaviour during accident scenarios.

– Hong M. Huynh

Session 8: Equipment and Design Qualification

The first part of the session was devoted to environmental qualification of equipment, with particular attention to in-service plants. Peter Lindsay opened the session with a bang by showing some photographs taken inside the TMI-2 containment after the accident. The damage to equipment caused by the hydrogen burn and radiation levels at the time of the accident was very obvious. He also showed a photograph of a charred transmitter which continued to operate after the accident despite this harsh environment. The presentations which followed outlined Ontario Hydro's large program now underway to review the environmental qualification of all critical safety system equipment within their operating plants. Geoff Burston then described Ontario Hydro's various training strategies designed to orchestrate the efforts of some 4,000 individuals who will contribute in one way or another to the EQ effort.

The second half of the session was devoted to two presentations: a non-linear dynamic analysis of pipe whip following a postulated main steam break at Gentilly 2 (by Medhat Attab of AECL-Montreal), and the structural design for a new dry fuel storage system called CANSTOR (by Wafik Ajam of AECL-Montreal), which is one of the concepts being considered for Gentilly 2. Both presentations were followed by a lively debate.

Andre Baudouin

Session 9: Compliance and Licensing

Seven papers on a variety of topics were presented in the Session. Although each topic touched in some way on the subject of nuclear plant safety and therefore had "compliance and licensing" ramifications, the presentations were all different from each other.

The differences notwithstanding, the papers fell into two basic groups: those that dealt with broader issues and those that focused on more specific, technical-nature issues.

In the first group there was what might be described as a "big picture" paper which looked at "risk-based value-impact analysis" and discussed how the decision to proceed with a proposal to change significantly a plant's design or its operation might best be made so as to be certain that it would be worthwhile from a public safety standpoint. Another paper reported on the novel approach being taken to license a "CANDU Standard Plant" and yet another examined the difficult question of how to exert good control over the continuously increasing volume of important documentation that is characteristic of every nuclear power plant. Finally in this group was an interesting and comprehensive presentation on the establishment of a global-nature Human Factors Engineering Program for new CANDU designs.

Reinforcing the latter paper but in the second group of more detailed topics, was a presentation on the functional role of annunciation. Finally in this group, there were two practical-nature papers written in the context of Point Lepreau GS and its continuing operational safety.

Every one of the presentations was interesting and informative and the Session was well-attended.

– **R. Thomas**

Session 10: Fusion Science and Technology

The session was opened with a paper by Gary Vivian, *et al*, discussing safety issues associated with Fusion power reactors, and providing a summary of the areas in which Canada is involved in the international fusion safety program. Much of the tritium safety technology developed in Canada for the CANDU program is being used to address tritium safety issues associated with fusion reactors.

The second paper of the session described a new concept for fusion reactors: the spherical pinch tokamak which E. Panarella believes is a strong competitor to the current torus "doughnut-shaped" machines, for demonstrating fusion power.

Guy LeClair summarized the R&D work being performed and planned at the Tokamak de Varennes. Much of the work being done at the Tokamak de Varennes on controlling plasmas by different methods will be of significance to the larger international experimental machines such as JET (Joint European Torus) or ITER (International Thermonuclear Experimental Reactor).

In the fourth presentation, Walter Shmayda provided an interesting presentation on practical means for minimizing tritium laboratory occupational doses. Recent efforts in the Ontario Hydro Tritium Research Laboratory have reduced tritium concentrations in the lab that approach background levels.

The fifth paper was presented by K. Torr and provided a description of a hydrogen isotope separation system developed and manufactured in Canada for KfK. The system uses the principle of gas chromatography to separate hydrogen isotopes from a helium gas stream. The KfK lab in Germany is part of the Euratom fusion program and this system will be used in support of that program.

The use of "pressure swing adsorption" for removing tritium from a helium gas stream was described by C. Fong. This method is being proposed as a possible means of extracting tritium from breeding blankets, which may eventually be tested in ITER. A preliminary design for an ITER pilot plant (1/40 scale) has been completed on the basis of laboratory test results.

Last, but not least, was a very interesting presentation by Roger Raman on the development of a novel fuelling machine for tokamak reactors. This machine, known as a compact toroid fueller, has the capability of accelerating tritium plasmas to speeds in excess of 300 km/s. A prototype machine has been constructed at the University of Saskatchewan, where it will receive preliminary testing before being shipped to Tokamak de Varennes for an experimental program there. Anticipating a successful program at Tokamak de Varennes, a similar machine could be built at ITER.

– **A. Natalizio**

Session 11: Darlington N12 Assessment

This was the first of two sessions covering the investigation into the fuel failures at Darlington. The first paper presented an overview of the investigation including the organisation and its changes over the last year. The four experimental loop fuel channels which were used, at STERN, AECL, SPEL, OHRD, and GE were then described, including some of the major conclusions from the work – that pressure pulsing at 150 Hz, caused by the pump, was responsible for the end plate cracking. Modelling of the DHT System acoustically, using ABAQUS and a program called WHAM were able to calculate the header acoustic mode shapes and had fairly good ability to predict problem channels.

Major work at the station has been aimed at returning Unit 2 to service. This has entailed the removal of two fuel channels. Planned return to service was August 15, 1992. Solutions to the problem were presented which included acoustic resonators, alternators, different pump impellers, etc. The seven impeller solution has been implemented in Units 1 and 3 to further understand the acoustics of the system.

– G.J. Field

Session 12: Plant Aging and Life Extension

Techniques for assessment of plant aging of all process system and safety system components in a CANDU power station were discussed. Methods for pro-active evaluation of equipment remainent life and maintenance practices for life extension were reviewed. W.M.C. Knowles of Ontario Hydro Nuclear Operations Branch presented a paper "Proposed Approach for the Management of Plant Aging" which identified current techniques being applied to assess station component aging effects at his utility. The need for inter-utility cooperation to identify standard assessment practices was identified.

Specific problems related to the impact on CANDU plant performance from fuel channel aging effects was highlighted. This has resulted in major maintenance outages at some Ontario Hydro units to replace pressure tubes. Plans are being assembled to replace pressure tubes in future at other stations owned by Ontario Hydro and N.B. Power. In the paper presented by S. Venkatapathi of AECL-Chalk River the positive results from the program for "Development of Flush Rolled Joints for Bruce NGS A Large Scale Fuel Channel Replacement (LSFCR)" were discussed. This paper in conjunction with the presentation by David Brown of AECL-CANDU on "A New Fuel Channel for Bruce NGS A" identified improvements available for future refurbishment of the Bruce fuel channels.

In addition, papers by A. Ditschun of AECL-CANDU on "In-process Control of Bellows Welding During LSFCR of CANDU Reactors," and the presentation by R.J. Gunn of AECL-CANDU on "Fuel Channel Installation Tooling for Retube of Bruce Reactors" described enhanced pressure tube installation practices which are now available. These promise to improve the quality and production rates for pressure tube installation, and expedite retube projects in future CANDU stations when required.

The session was well attended, and the vigorous question sessions following each presentation were a testimony to the interest expressed by the nuclear industry regarding utility programs for dealing with aging effects in fuel channels. In future meetings, discussion on aging effects in components such as steam generators, turbines, generators, balance-of-plant piping, and special safety systems are expected to stimulate additional interest.

– S.H. Groom

Session 16: Operator Training and Certification

This session addressed the important topic of operator training. The first paper, entitled "Towards a New Regulatory Regime for Nuclear Operator Certification," was given by Ron Thomas of the AECB. He outlined the early history and background related to the activities of the AECB in assuring the competence of senior operations personnel in the main control rooms of Canada's nuclear power stations. He went on to outline the major changes being planned that would involve the systematic evaluation of nuclear operator training programs by the end of fiscal year 1991/92 and the full-scope simulator-based testing of candidates in 1993. When in place, the new arrangements for nuclear operator certification should be among the best in the world in terms of their balance and appropriateness.

Andre Vachon provided further details on the "Emerging Canadian Regulatory Approach." He discussed the simulator characteristics that are required for operator certification examination purposes and also described the method for selecting and developing test scenarios, the performance measurements and assessment criteria that will be used to establish a reliable and valid assessment.

Larry Watt's paper "X-TEND – An Expert System for Use as a Training Aid in Trip Parameter Assessment" was an excellent graphic presentation of simulation data that enables the user to quickly gain an understanding of the order in which events occur, and the conditions that precipitate them. X-TEND, developed at Idea Research, is intended for use primarily by analytical staff at nuclear facilities, students, station operators and managers.

Dave Reeves followed with a presentation on training based on enhancing understanding of critical safety parameters (CSPs). The objective of CSP training is to assure that control room staff can monitor and control a discrete set of plant paramaters (CSPs) that, if maintained within acceptable bounds, result in adequate fuel cooling at all times. The fuel cooling fundamentals approach, developed by Dave Reeves and colleagues, has been adopted at Point Lepreau GS and it is judged to be of substantial merit to the overall training program.

Syd Turner outlined "A Trainer's Perspective" on the assessment of training effectiveness. Syd expressed concern that there is no appeal/review mechanism of the results promulgated by the regulator and that the examination process is of little value in respect to the day-to-day control room operating staff job function. Rather, deliberate, diagnostic thought processes are one of the essentials to safe operations. In discussion, it became clear that even the AECB has recognized this and the move towards the new regulatory regime described by Ron Thomas will go part of the way to alleviating those concerns. Another paper from Lepreau by Bob Simpson described the comprehensive approach used in the Mechanical Maintenance Training Program.

Ontario Hydro's requirements for Simulator-Based Testing of Candidates for Authorization was presented by Graham Hancock who emphasized the four main technical requirements that a training simulator must meet in order to support the testing of candidates for authorization. These requirements include (i) reliability, (ii) capability, (iii) fidelity, (iv) data logging facilities. Spirited discussion followed on the concept of fidelity and the requirements identified by Ontario Hydro.

This was an excellent session attended by approximately 20-25 at all times with good discussion and cross-fertilization of ideas.

Jatin Nathwani

CNS Submission to the Environmental Assessment Board on Ontario Hydro's Demand/Supply Plan

Summary

This submission commends to the Board the findings of more than thirty previous inquiries into nuclear energy, and summarizes the benefits to Ontario of the technology. The conclusion of the Canadian Nuclear Society, in common with many of the inquiries, is that nuclear energy is not only an acceptable source to contribute to the supply but, in some circumstances, is the source of choice.

Introduction

The Canadian Nuclear Society consists of 750 Canadian scientists, engineers and other professionals. More than 75% of our members are residents and taxpayers of Ontario, and users of electricity generated by Ontario Hydro.

The Society's objectives are:

- to act as a forum for the exchange of information relating to nuclear science and technology, among diverse specialists, affiliated associations and others;
- to hold meetings for the presentation, discussion, and publication of scientific, technical and other papers relating to nuclear science and technology;
- to organize branches which will provide focal points for the individual and regional interests of members across Canada;
- to organize technical divisions which will provide for the individual, scientific and technical interests of members;
- to foster the development and utilization of nuclear science and technology for peaceful uses.

The society, through the activities of its members in many disciplines, is conscious of the vast amount of relevant information in the public domain, making it difficult for an outsider to know what is available on any given topic. We hope that this brief submission will be of help to the Board in this respect, and we assure the Board of our willingness to provide such explanatory or supplementary information as it may feel helpful, to the extent of our capabilities and resources.

This submission addresses the interests of the Board's Option (3g). Having no special expertise in demand forecasting, we will not comment on Ontario Hydro's forecasts beyond noting that there is strong evidence[1] that the electricity demand has been firmly tied to Gross Provincial Product (GPP) for several decades, through boom times and recession, through energy glut and energy shortage.

Canadians use electricity mainly to produce goods and services, thus a plan for low electricity demand could turn out to be a plan for high unemployment. History shows that one statement can be made with confidence about any forecast: It will turn out to be wrong. The future demand of electricity will be determined by the day-to-day activities of businessmen and of millions of individuals exercising free will in unknown economic conditions. We trust that the Board will consider this large uncertainty in making provisions on the supply side to which nuclear energy contributes. If one had to choose between electricity shortage and electricity surplus, the latter seems to us to be the wiser and safer choice.

Nuclear Option

The CNS recognizes and supports many of the arguments that will be put forward at the hearings by the supporters of the nuclear option, including:

- the acceptable environmental impact and safety features inherent in the generation of electricity by nuclear technology;
- the excellent environmental and safety record established over the past twenty-five years by the CANDU program, especially compared to other options for the generation of electricity;
- the long term economic advantages relative to other forms of electricity generation; and the overall benefits to Ontario and the nation of pursuing the CANDU option;
- nuclear technology spin-offs such as the medical isotopes, radiation processing and process control technologies;
- enhanced technology exports, and intellectual capital gains;
- avoided net fuel imports, fossil fuel price capping and electricity price stability;
- avoided acid and greenhouse gas emissions;
- the need for Ontario to maintain an adequate supply of electric generating capacity;
- the recognition that any excess capacity can be exported, thereby improving Canada's export/import balance.

Previous Inquiries

Some of the above issues have been addressed in previous inquiries and studies performed in various jurisdictions around the world, and a comprehensive list of these is attached for reference purposes. A survey of these inquiries by Robertson[2] shows that, contrary to some claims, virtually every aspect of the nuclear controversy has been subject to detailed scrutiny. The inquiries' reports include recommendations on *how* nuclear energy can be exploited more safely, but none reject nuclear as an acceptable energy source.

It is claimed by some that the risk of nuclear accidents, or the problem of waste disposal, or the possible diversion of fissionable material to weapons usage makes nuclear electricity unacceptable. However, these and other claims have been critically examined by independent inquiries and rejected. It is similarly claimed by some that the promise of conservation, and of renewable energy sources (excluding hydroelectricity) makes nuclear electricity unnecessary. Again, these claims have been examined and rejected.

Benefits of Nuclear Technology to Ontario

Having seen that there is no logical reason to exclude nuclear energy, let us examine why it should be included.

- The health of the citizens of Ontario must be a primary concern. The Advisory Committee on Nuclear Safety (ACNS), an independent advisory committee to the AECB, has recently[3] published a review "Alternative Electrical Energy Systems – A Comparison of the Risks of Occupational and Public Fatalities" (ACNS-10). It concludes that the occupational risks of the coal fuel cycle are about two to four times higher than those from the nuclear or hydraulic systems, and that the public risks from coal-fired systems are also somewhat higher than those from nuclear or hydraulic systems.
- The environment, a priority concern for Ontarians, is another area where nuclear energy has a clear advantage over available features. Approximately 18% of Canada's CO_2 emissions in 1988 were from burning fossil fuels to generate electricity.[4] A large proportion of these emissions could be eliminated by the use of nuclear power as described in various plans submitted to this Board by Ontario Hydro.
- The nuclear option ensures the long term security of energy supply to Ontario. Concerns[5] have been raised about policies that advocate increased use of natural gas through parallel generation and load shifting from electricity. Natural gas is projected to become increasingly expensive and uncertain early in the next century.
- Increased economic activity and employment also argue for nuclear energy. The nuclear option supports a high-tech industry that provides highly-skilled jobs for our scientific and engineering population, most of them in Ontario. The nuclear industry supports nearly 30,000 direct and nearly 100,000 overall jobs in Canada. The economic contribution was more than $4.5 billion in 1990. This is important to the socio-economic well-being of the province, and therefore becomes a significant factor to be considered in the environmental assessment of Ontario's future energy options.
- Nuclear and other high-tech industries encourage and attract students to scientific and engineering disciplines. Concerns have been raised by Industry, Science and Technology Canada[6] about the "declining enrolment in science and technology-related programs at the college and university levels, just when we need more scientists and engineers, technicians and technologists to enhance our industrial competitiveness and economic prosperity. Elementary and secondary school students are increasingly choosing to avoid science and math." Thus it is important for the socio-economic well-being of Canadian society that the CANDU option be maintained.
- Nobody can assure that Ontario will *not* need nuclear energy in the 21st century but if it is allowed to atrophy it will not be available. Shortage of expertise and manufacturing capabilities will undermine the ability of the nuclear sector to respond to future needs.

Conclusions

The Canadian Nuclear Society submits that there are good technical and social reasons for Ontario Hydro's future supply to be based on a mix of technologies and that the nuclear option should be a part of this mix. There are no valid reasons for excluding it. Indeed, a detailed comparison would show it to be the source of choice.

As a society of professionals with certain scientific and technical expertise, we recognize that ethical issues are involved in energy decisions. Those of us who are Professional Engineers have our own code of ethics. If nuclear energy is criticized on ethical grounds, as sometimes happens in energy debates, we recommend that the Board consider the arguments advanced by Robertson[7] in the Society's *Bulletin*.

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The Geometry of Nuclear Energy: Getting the Right Angle on the Ethics

by J.A.L. Robertson

Abstract

In a personal assessment of the ethics of nuclear energy, the author challenges some of the conventional wisdom surrounding the subject, and concludes that for many applications nuclear energy is the energy source of ethical choice.

"To see what is right and not to do it is want of courage."
– CONFUCIUS

Introduction

Proponents of nuclear energy usually base their case on technical aspects, while opponents tend to criticize it on ethical grounds. Too often the two sides have simply been talking past each other.

Many of those opposed to nuclear energy have argued for ethical questions to be included in the debate, presumably believing that this would support their arguments. I strongly support any examination of the ethical questions, but for the opposite reason. My thinking over several decades has convinced me that for many applications nuclear energy is the energy source of choice from an ethical standpoint. We need not only to do things right, but to do the right things. Here I will explore what I consider to be the relevant ethical issues with particular reference to nuclear waste, since this is a serious public concern that is currently being examined by a federal Environmental Assessment Review Process (EARP) Panel for Nuclear Fuel Waste Management. However, to lay the necessary groundwork, I will first imitate Euclid by stating and explaining a few axioms and theorems that apply to nuclear energy in general but do not seem to be widely accepted.

Axioms and Theorems

Let your conscience be your guide. In the early days of nuclear energy it was welcomed by church groups and environmentalists. When opponents began to criticize it as unethical I tried to educate myself on the academic discipline of ethics. However, the deeper I went the more esoteric the subject appeared, and often confused by religious dogma. I found little to help anyone make ethical choices in real life, and concluded that each of us has to rely on our own conscience. This is not original or revolutionary: The Canadian judicial system requires juries to determine whether the accused knew right from wrong at the time of the crime.

It's better to do good than to do harm. It is easy enough to formulate ethical principles in the abstract – Moses came up with, or down with, ten. The difficulty arises when two conflict, or when no principle fits exactly the practical issue. Most of us subscribe to "Thou shalt not kill," but there is serious disagreement over if and when war and capital punishment are justified. In practice, one must often compare practicable options. To provide some guide for my conscience, my ethical choice is the one that yields the greatest good for the greatest number, subject to some protection for minorities (termed "utilitarianism" in professional ethics.) The real problem in many ethical decisions is balancing majority and minority rights, but I am reinforced in my belief by the fact that most democracies support this principle and have the same problem.

Good intentions are not good enough. By making my conscience my final arbiter I may seem to be saying that if anyone feels strongly and sincerely about something that in itself makes it ethical. Such is not so. Thus I add to my prescription the obligation to examine the issue thoroughly before passing it to one's conscience for a judgement.

Facts matter – Shortly after the Chernobyl reactor accident in the U.S.S.R., while out cutting the grass I narrowly missed mashing a frog. At each successive pass I found that it had moved further into the uncut grass, where it was barely visible. Unjustifiably assigning intelligence to it, I supposed that it perceived the risk of being caught in the open by a predator as greater than that of being run over by the power mower. Knowing that I would continue until all the grass was cut, I felt that it was making an unwise decision based on an inadequate knowledge of the real risks. I was greatly frustrated by my inability to communicate to it why, in its own interests, it should do the opposite of what it was doing. Earlier that day I had heard on CBC Radio that some Canadians were exhibiting fear, bordering on hysteria, of the radioactive fallout from Chernobyl. Despite assurances from federal authorities that the radioactivity, though detectable, was not dangerous, parents were keeping their children indoors. Apparently they were unaware of the fact that the radiation due to naturally occurring radon in the average dwelling is about a hundred times the radiation from fallout experienced outdoors. From a lack of knowledge of the facts, they were doing the exact opposite of what they intended.

– and so do figures. Once one accepts that real ethical decisions involve choices between alternatives, it is necessary to quantify costs and benefits wherever possible. As Lord Kelvin said: "When you can measure what you are speaking about and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind." To ignore available figures would be unethical. This point can be illustrated by reference to botulism. A U.S. study[1] showed that while botulism actually causes two fatalities per year in that country, public estimates ranged from 100 to 3000. If society, knowing the fact that botulism causes only two deaths per year, makes the value judgement that a large amount of its limited resources should be committed to combatting this risk, I can accept that democratic decision. However, I would appeal the same decision if it were made on the false belief that botulism causes 500 deaths per year. Facts and figures do matter.

C.P. Snow Lives! In the 1950s, the British scientist, academic, novelist and later cabinet minister C.P. Snow drew attention to what he described as the Two Cultures that divided western societies. In the one camp were those of an artistic or literary bent, the self-styled "humanists," and in the other the scientists and engineers, with a vast gap in values and communication between them. Snow argued that closing the gap is essential, otherwise "no society is going to be able to think with wisdom." Unfortunately, there is no evidence for progress in the past forty years. What I, as a scientist, find particularly depressing is the hubris of those who take a pride in being scientifically illiterate and innumerate: One hears the boast "I am a technomoron." The relevance here is that, where facts and figures matter, such people are unlikely to reach wise decisions – they remind me of the frog in the grass. To make matters worse, those who do try to inform themselves on nuclear questions have to rely on the media, which are almost wholly populated by those from the first camp.

There's no risk-free lunch – One result of the media's failure to quantify is that the public rarely has a scale against which to measure the severity of the daily "disasters" dispensed by the media. Telling people that 30 potentially cancer-causing chemicals have been detected in the Great Lakes, without saying how much water would have to be drunk to cause any harm, is irresponsible. Individuals are not only being scared unnecessarily, they are being misled into believing that absolute safety is attainable and something to which they have a right. In fact, everything we do carries with it some risk. By not going to work we can avoid occupational risks, but if we stay home the risk of an accident is probably greater. Even staying in bed is no guarantee of safety: The house could be demolished by an earthquake, a fire could start in the adjacent apartment, and trucks have been known to run off the road into a bedroom. Life is a sexually transmitted condition that invariably proves fatal. To provide the public with some perspective on the risk from radiation, it has been compared with the risk of smoking cigarettes, a familiar activity for which the risk has been well quantified. On the very rare occasions that workers at a Canadian nuclear generating station have been exposed to radiation beyond the regulatory limit it is front-page news: The public is not told that the limit is roughly equivalent to the health risk from smoking two cartons of cigarettes.

– **not even a peanut butter sandwich.** Because many people who consider smoking disgusting were rejecting the comparison, I sought and found an alternative, in peanut butter. It is right up there with apple pie as representing everything that is wholesome, and is even sold in health-food stores. And rightly so – it is a good, inexpensive source of vegetable fats and protein that kids actually like. But it is associated with a finite risk. Peanuts can be contaminated with a lethal poison, aflatoxin. Statistically, if I eat a jar of peanut butter I have a one-in-a-million chance of dying as a result. To me, this means that peanut butter is not dangerous but safe. However, each of us has to decide for ourself whether the risk is acceptable and whether we are being irresponsible feeding it to our kids. Using this comparison, the public risk due to radiation from a Canadian nuclear station is less than that from eating one peanut-butter sandwich each week. If nuclear energy is to be labelled as a hazardous energy source, so should peanut butter.

"Perception is reality?" – False! It is sometimes argued that public policies should be based not on the real risk but on popular perception of the risk. This would have stopped automobiles and electricity before they started since, in their early days, both were perceived to be much more dangerous than they actually were. Automobiles had to be preceded by flagmen and electric switches bore a sign "The use of Electricity for lighting is in no way harmful to health, nor does it affect the soundness of sleep." To study what affects people's perceptions of risk, Slovic *et al.*[1] asked four different groups in the U.S. to rank in order of their threat to life thirty different activities and technologies. Two of the three lay groups (members of the League of Women Voters, college students and members of an "Active Club") perceived nuclear power to be the riskiest, while the fourth (experts in risk assessment) ranked it twentieth. When asked to estimate the fatalities to be expected from these activities and technologies in an average year, the experts predictably exhibited a closer correspondence with actuarial values and a greater differentiation between activities than the lay groups, but this did not explain the difference over nuclear power. However, when asked to estimate how much worse things would be in a particularly bad year, lay groups considered that the fatalities from almost all the activities and technologies would roughly double, but that those from nuclear power would increase approximately a hundredfold.

Thus people's perception of the risk from nuclear power involves a dread of possible disaster. Slovic's study did not examine whether the lay groups knew of, but disbelieved, inquiries that show such a disaster to be extremely improbable in North American reactors. According to those who conducted the study,[1] human nature is such that people confronted with evidence of a risk tend to reject either the evidence or the cause of the risk, depending on their existing beliefs. "New evidence appears reliable and informative if it is consistent with one's initial belief; contrary evidence is dismissed as unreliable, erroneous, or unrepresentative. Thus, depending on one's predispositions, intense effort to reduce a hazard may be interpreted to mean either that the risks are great or that the technologists are responsive to the public's concerns. Likewise, opponents of a technology may view minor mishaps as near catastrophes and dismiss the contrary opinions of experts as biased by vested interests."

"The only thing we have to fear is fear itself" - *F.D. Roosevelt.* The importance to public perception of a "dread factor" was illustrated by a study by Fischoff *et al.*[2] They first ranked five energy technologies according to their risk to human health, from available statistics on deaths and morbidity; then again but including estimated "dread factors," measures of stress and anxiety. In the first ranking, nuclear energy came out best, better even than energy conservation. However, when dread factors, given weight equal to deaths and morbidity, were included conservation became best and nuclear dropped to fifth place, better than only large wind generators. Thus, if the dread is justified and inevitable, the continued use of nuclear energy must be questioned: If not, it is the dread that should be tackled, by improved information. Facts really do matter!

How safe is safe enough? Generally, the public is not interested in discussing risk, as defined by experts, or the probability of a disaster, but wants to know if something is safe or not. This gives regulatory bodies and public inquiries the problem of deciding what is "acceptably safe." One approach is to demand that no risk should be tolerated, but this is unrealistic since every human activity is associated with some risk. A more pragmatic approach has been to assess what risk the public actually accepts in practice, differentiating between voluntary and imposed risks, then to say that what is accepted is acceptable. This, however, ignores both the possibility that the status quo may have been accepted only reluctantly; and the continuous improvement in safety that characterizes our society. Another suggestion has been that our elected representatives should set an "acceptably safe" level of risk, that could be updated from time to time, and leave it to the various regulatory bodies to ensure that that level is achieved in their areas of responsibility.

This presents a practical problem of dealing with risks just one side or the other of the limit, but a greater difficulty is that it ignores the benefits and costs associated with the risk. Nobody wants any risk, however small, unless it is associated with some net benefit. The conclusion is that no risk can be considered acceptable in the abstract, but a judgement has to be reached in a comparison between available alternatives, considering risks, benefits and costs. If there is no alternative, the existing risk is acceptable, no matter how high. The answer to the question "How safe is safe enough?" is "The best alternative, all things considered."

How safe is too safe? In practice, "all things considered" gives difficulty. Benefits and costs can be weighed in monetary terms to yield a net benefit, but how can this be balanced against the risk? Even in today's advanced societies there are still many opportunities for improving health care and safety, while in the Third World the potential is virtually unlimited. Many improvements would eventually have an economic payback but initially all require some financial cost. In Canada recent political debates over the cost of the health-care system have made us well aware that resources are severely limited, so that resources devoted to one worthy objective are unavailable for others.

Quantifying the costs reveals a staggering variation between the options available to us.[3] For instance, a million dollars spent on certain highway improvements or on mobile cardiac units can be expected to save about 30 lives, while it would take about a billion dollars spent on improved automobile standards for carbon-monoxide emissions to save a single life. If this is extended to the Third World, a million dollars spent on vaccination or rehydration solutions can save about a million lives. You get what you pay for - give or take a billion! However, some people oppose the use of these statistics for risk assessment, apparently finding it abhorrent to "put a price on human life" in this way. What I find abhorrent is a willful refusal to face facts resulting in the loss of lives that could be saved by a more rational allocation of limited resources. To save their delicate scruples they are willing to condemn to death many anonymous individuals to whom they will never have to defend their actions.

This objection can be overcome by an examination of the alternative. The money spent to reduce a risk cannot be used for anything else. If the money were to be freed, not all of it would be used to reduce risks elsewhere but some would. Siddall[4] estimated that for every $7 million (in 1982) increase in an industrialized country's gross domestic product (GDP), one fatality would be avoided due to the fraction of GDP devoted to activities that reduce risk, e.g., health care and fire protection. Thus, instead of balancing the net benefit against the loss of life in dollars, one can balance the lives saved by a safety measure against the lives lost through the use of society's limited resources for that purpose. Viewed this way, the question should be not "How safe is safe enough?" but "How safe is too safe?". Any measure costing more than about $10 million to save a life may be counterproductive.

Wealth is good for health. Life-expectancy statistics for North America and Europe during the past three centuries[5] show that as society's wealth has increased so has its individuals' longevity. Since we are now living longer than our forefathers, the world must be safer, not riskier. All the horrors of the industrial revolution and modern industrialization were accompanied by a doubling in the life span. In more recent times, the relative death rate of social groups in the U.K. decreased as the income rose; the infant death rate in Canada was higher in the poorer provinces than in the wealthier ones until a national health-insurance program was introduced; and life expectancy in the U.S. for unskilled labourers was 6.5 years less than for corporation executives, with professional, technical, administrative and managerial workers coming somewhere between[6] For a forty-five-year-old man working in U.S. manufacturing, a 15 per-cent increase in income has been estimated to have about the same risk-reducing values as eliminating all hazards in the workplace. The recent cholera epidemic in South America was due to poor sanitation and occurred among the poor: Cholera is a plague of poverty.

Wealth does not cause, but allows, health. Money may not make us happy but it lets us be unhappy in comfort - and for a lot longer! In assessing the health effects of any energy source it is not fair to count only the harm, without also considering the benefits resulting from the wealth that the energy generates. When I apply this precept to nuclear energy, I conclude that on balance it does not cost lives, however few, it saves them. The operation of a large Canadian nuclear plant may indirectly result in one death per year from all causes, for comparison with the two electrocution deaths per year resulting from the use of its product, and an estimated 10-20 lives per year *saved* by the increased wealth generated.

Energy is good for us; more is better. Because energy consumption is strongly related to wealth, much of what has been said of the benefits of wealth apply equally to energy. There is a strong correlation between life expectancy and energy consumption per capita in modern societies. Although a correlation does not prove a causal relation, plentiful energy is essential for most of the developments that have contributed to a longer life. General improvements in living standards, such as better sanitation, better housing, a readier supply of clean water, better nutrition and better means for food preservation, have been more important than medical developments. Engineers may have saved more lives than doctors. If, together, they are to continue saving lives they will need plentiful energy.

More equity demands more energy. As long as there is a correlation between energy per capita on the one hand and health and wealth on the other, whatever the reason for it, improving the lot of the poor is going to require more energy. Improving energy efficiency will result in the increase being less than otherwise, but an increase will be necessary to reduce poverty, in Canada or internationally. The Gross Domestic Product (GDP) of a country or a province correlates even better with consumption of electricity than of energy in general. Canadian experience over the past decade has demonstrated that unemployment is the most effective means of reducing electricity demand, and that economic recovery results in a resumption in demand. Full employment, a worthy objective, will require more electricity. Quantifying the demand, each dollar increase in the GDP requires only a nickel's worth of electricity, but if that nickel's worth is not there the economy and hence the social services will suffer.

Electricity the great emancipator. According to Homi Bhabha, a nuclear-energy pioneer in India, "No power is as expensive as no power." He could appreciate the value to the quality of life of even one water-pump per village or one light bulb per dwelling; and also the absolute necessity for adequate electricity for a country wishing to industrialize. On average, each man, woman and child in Canada depends each day on energy equivalent to 21 litres of oil. For comparison, the food we eat each day has an energy equivalence of less than 0.2 litres of oil. So each of us enjoys, free from guilt, the services of about a hundred "energy-slaves." Just as coal and the industrial revolution did more than Abraham Lincoln to free the slaves, so electricity has done more to emancipate women than all the political speeches on the subject. Ready access to electricity has removed much of the drudgery from "women's work," and has thereby made us men willing to share it to some extent. Without modern electrical appliances, career women would still represent an insignificant minority.

The world does not owe us a living. Some nuclear critics object to generating electricity for export. What is wrong with exporting electricity? As long as we want to import oranges, electronics, automobiles, or anything else, we have to export something to pay for them. All export industries, from agriculture through forestry and fishing to mining, involve some wastes and harm to the environment and health. Indeed, these examples are among the industries with greatest occupational health hazard. Anyone objecting to the export of electricity should be obliged to explain what could replace it, and how it compares with respect to health, the environment and wastes.

I conserve, you save, he is a miser. Having grown up in the U.K. during the depression and wartime, I am a pre-founding member of "The Conserver Society." Until it was invented I was simply a mean Scot. Now, however, conservation has been given a bad name by the humbug of those who preach saving energy as a religion without regard to the use. I find it ironic to see outspoken civil libertarians jetting around the country to demand that others not use energy for what they regard as luxuries ("Let my conscience be your guide"). Some energy is needed if we are to survive, preferably in reasonable comfort, in a harsh climate; more is needed if we are to have jobs, and I have already argued the health benefits of energy.

Fortunate societies, with a surplus of energy above the survival level, enjoy leisure and a choice of activities such as education, recreation and travel. Are these luxuries? Who is to decide? If, having earned money, I wish to spend it on energy why should I be made to feel guilty, while someone else saves energy and uses the money saved to buy something that consumes energy in its production and use?

It is waste, not energy, that is the enemy and waste of all resources, not just energy, that should be attacked. True conservation would *use* plentiful energy to *save* other scarcer resources. Saving without substitution is a palliative and not a panacea. Conserver zealots fail to point out that switching to more efficient lights and refrigerators, through their "waste heat" having to be replaced by the furnace, can result in plentiful electricity from hydroelectric or nuclear sources being saved, but more scarce oil being used.

People are the principal pollution problem. Unless and until population growth can be capped there can be no solution to any of the other problems, including energy, food, arable land, clean water, acid rain and global warming. With the world population stabilized at some manageable level, plentiful energy can contribute to the solution of these other problems. However, most energy critics ignore this, possibly for fear of antagonizing a powerful religion. This has been described as a "conspiracy of silence," but I would never infer a conspiracy when simple ignorance will explain the facts.

Small is beautiful; large and rugged can't be cheap. Nonrenewable energy sources cannot be a permanent solution. From this truism advocates of the so-called "Soft Path" argue that we must convert to renewable energy sources. This too is indisputable: What is at issue is the period over which to make the conversion. Strictly, nuclear energy is a nonrenewable energy source since uranium, or another nuclear fuel, is consumed. However, with fuel recycling, there is enough nuclear fuel to last for hundreds of years, and probably longer. Thus the choice between nuclear and renewable energy sources should be made for other reasons, primarily cost and health- and environmental-effects.

There is a widespread myth that renewable energy would be economically competitive if only we were to spend more on its research. However, as Goethe pointed out long ago, in deciding what to leave undone it must be remembered that the value of a project depends on the chance of achieving useful results as well as on the importance of the results if achieved. We do not need science, only common sense, to understand why renewable energy can never be cheap, however many technical breakthroughs we want to assume. Renewable energy, notably solar, wind, geothermal, tidal and wave energies, is both dilute and intermittent. Consequently, there must be large collection structures as well as a storage system, and if these are to last for decades they must be rugged. There is enough engineering experience to tell us that large rugged structures can never be cheap. One qualification is illuminating: Renewable hydroelectricity, while never cheap, is cost competitive. The reason is that nature provides most of the collection and storage structures, the watershed basin, so that man has to provide only the dam. It is as if one got a bottle of wine for the cost of only the cork. Such bargains are rare. Despite this, there are places and applications where renewable sources, other than hydroelectricity, are attractive, mainly where isolation makes conventional sources not readily available. Small may appear beautiful under certain circumstances but anyone who thinks that decentralization solves all problems should read Sinclair Lewis' "Main Street." The conclusion is that energy sources should be chosen on their merits, not as a matter of semantic dogma – my Principle of Anti-Semanticism.

Anyone advocating renewable energy without regard to cost should face the fact that this can be done only by sacrificing other desirable objectives.

Where you stand depends on where you sit. Many critics assume, implicitly or explicitly, that nuclear energy represents an unacceptable risk and, specifically, that the wastes cannot be rendered safe by any technological or institutional fix. If this were valid, their opposition would be understandable and reasonable. Indeed, not to oppose nuclear energy would be unethical. Nuclear proponents challenge the assumption, believing nuclear energy to be more benign than available alternatives. If the waste-management concept currently under review by the EARP Panel is found to be acceptable, how many of the objections would be valid?

Ethical Issues of Nuclear Wastes

Solve the waste problem by not producing wastes? Opponents of nuclear energy have suggested that the best way to manage nuclear wastes would be to stop producing them, so that the problem would be confined to disposal of what has already been produced. This seems reasonable until one examines the three possible consequences of such a decision: (1) Conservation measures would compensate for the nuclear energy not produced, (2) the energy needed would be produced from some other source, or (3) there would be energy shortages. Having recognized that energy in general and electricity in particular are put to good and valid use, one must reject the third as unethical.

A decision on the second requires a detailed and quantitative cost/benefit analysis, including health and social costs and benefits, for the alternatives. When this has been done nuclear energy is usually well in the running, with the final decision depending on site-specific factors such as the accessibility of untapped hydroelectric resources.

For the first, most people would agree that cost-effective, non-coercive conservation would be preferable to nuclear electricity, even though both may generate wastes in their achievement. Here the problems are in deciding just how much of this conservation there is available and how much will be achieved in practice. The fact that Ontario is currently engaged in a very expensive and prolonged inquiry to assess the three options indicates that it is far from obvious that nuclear energy is unneeded. My personal conclusion on this point is that waste management must be an important factor in energy policy but not an overriding ethical criterion: A judgement should be reached from a full assessment of all the costs and benefits. Just as everyone enjoys a good meal but nobody wants to wash the dishes, we all want the energy without the wastes. However, nobody stops eating just to avoid washing dishes.

But what about the risk? Most public concern over nuclear energy relates not to what is happening, but to what might happen: People fear a reactor accident or a waste-repository failure that would release large amounts of radioactive material to the environment. For nuclear energy it is not historical but hysterical risk that dominates the debate. The fact is that more people in North America have been killed by lawn mowers than by power reactors. The Ontario Nuclear Safety Review is the latest of a series of official inquiries to conclude that the risk of a serious reactor accident is very remote, and the current EARP Panel is examining whether the risk from a waste repository is acceptable. Nuclear proponents argue that these risks are negligibly small, or less than the risks associated with alternative energy strategies. We have generally ignored the risk from shortages of energy, specifically electricity. It might take major power cuts to cause deaths through food spoilage, disruption of sewage plants, lack of street lighting, etc., but modern industry is highly dependent on a reliable electricity supply and would be severely penalized by even minor cuts. Activities using computers, all-pervasive in today's society, are particularly vulnerable to supply interruptions. A voltage dip at Inco's plant, lasting only a tenth of a second, resulted in the need to recycle a quarter of a million pounds of nickel, while at Honda's Alliston plant a two-second interruption would require fourteen cars to be trashed. We have seen how the resulting loss of national wealth would have consequences for public health. These risks, from a shortage of electricity, are just as real as the ones causing greater fear.

Responsibility for future generations. In 1975 Atomic Energy of Canada Limited (AECL) stated that the objective of nuclear-wastes disposal* is "to isolate and contain the radioactive material, so that no long-term surveillance by future generations will be required, and there will be negligible risk to man or his environment at any time." Today, the statement can be criticized for its sexist wording, but not for its ethics. The concern for future generations was confirmed, in slightly different words, by the Atomic Energy Control Board's (AECB) 1987 Regulatory Policy Statement on objectives for the disposal of radioactive wastes, thus:

"– to minimize any burden placed on future generations,
– (to) protect the environment,
– (to) protect human health, taking into account social and economic factors.

Nuclear proponents in the 1970s, assuming that fuel would be recycled and that this would result in disposal of only the separated true wastes, interpreted this concern as meaning isolating the wastes from the human environment and rendering them inaccessible. Since then, with the need for

* "Disposal" implies permanent emplacement with no intent to retrieve the waste, while "storage" implies the intent of retrieval at some time.

recycling receding as more uranium was discovered, the proposal has emphasized disposal of intact fuel bundles, and hence of a potential energy source in the unconsumed uranium and plutonium in the fuel. This has made some people question the right of the present generation to *deny* future generations access to an important energy source. Our generation can pick and choose between energy sources, a luxury that future generations will probably not enjoy. Advocates of marginal pricing for electricity argue that current users are being subsidized. By whom? By a *past* generation which invested in capital-intensive, inflation-proof hydroelectric projects. In just the same way we will be "subsidizing" a future generation with our investment in nuclear plants. This should be put in the balance when weighing our legacies to future generations and our responsibilities to them.

How can one protect future generations without unacceptable paternalism – a problem faced by all parents? There is a logical fallacy in supposing that a decision for indefinite storage means giving future generations the choice between continued storage and disposal: Only by choosing continued storage, i.e., by not exercising true choice, can each generation pass on this opportunity for non-choice to the next one. The first generation to choose disposal denies resource recycling to all further generations. There is no ethical principle of equity that gives that generation preference over the present one for making this choice.

Trust future generations to find a solution? Some critics have suggested that the used fuel should be stored indefinitely in the expectation, or hope, that some new technology for the better disposal of radioactive wastes will be discovered. The pace of technological development in the 20th century encourages this attitude and no responsible scientist can guarantee that such a discovery will not occur. However, since there can never be a perfect solution to a practical problem there is no end to this policy of postponement: It will always be possible to postulate something better. The responsible approach to the management of nuclear wastes, as for other technological policy decisions, is to *implement an acceptable solution*, and not to use uncertainty as an excuse for inaction. As Voltaire said: "Le mieux est l'ennemi du bien." There is a certain irony in the fact that often those who trust future scientists to provide a better technology do not trust present scientists in their assessment of present technologies.

Can science predict nature? Some oppose geological disposal on the grounds that geology is an inexact, descriptive science that does not allow reliable predictions for thousands of years. This attitude can be intuitively appealing if one compares geology to meteorology, which has only limited success in predicting tomorrow's weather. However we all, and not just the scientists, accept with absolute confidence the predictions of astronomy, that the sun will rise at a certain time, that Halley's Comet will return at regular intervals, and so on. Geology lies between meteorology and astronomy in predictive capability. Whether its capability is adequate for the present purpose cannot be decided by analogy but must be carefully assessed on the facts. Facts matter and the EARP Panel will presumably be looking to its Scientific Review Group, composed of independent, recognized scientists, for an informed assessment of the ability of geology to make predictions within limits necessary to assure the safety of the proposed concept.

Temporal equity. Although there is general agreement that our wastes should not result in a significant risk to future generations, there is a lack of agreement on just what this means. The AECB's proposed criterion seems reasonable: That for any individual the predicted risk of a fatality should not exceed one in a million, which means that the individual's exposure to radiation from the wastes should not exceed a few percent of the exposure from natural sources and that it should lie well within the variation of natural exposures across Canada.

The problems are whether we need an additional criterion limiting the collective population exposure to future generations and, if so, how long into the future. The difficulty lies in the application of the widely accepted Linear Hypothesis, according to which the risk of radiation-induced cancer (and genetic defects) is linearly proportional to the dose, e.g., halve the dose, halve the risk. A mathematical consequence is that however small the dose, short of zero, there is some finite risk. Thus, even if all the individual doses are extremely small, well within the limit, by summing over all future generations for infinite time, one predicts an infinite number of cancer deaths: One can predict any number one wishes simply by choosing an appropriate period over which to sum.

One response is to limit arbitrarily the period to one comparable to recorded human history and the time between ice-ages, e.g., 10,000 years. Another is to regard any dose below some low value as negligible and therefore to perform the summation for only those doses above the minimum limit. One justification for this latter response is that doses greater than this minimum are regularly received, without any concern on the part of the public, from many other activities, such as aircraft travel, living in dwellings of certain constructions, or living at elevated sites. Another justification is that it is not possible to estimate the offsetting benefits accruing to future generations, even after the current version of nuclear energy is no longer used: Apart from providing energy during periods of shortage for the intervening generations that will produce future generations, it will contribute to the technical and social advances that future generations will enjoy. If this is hard to understand, just think how much this generation owes in health, welfare and social justice to the Industrial Revolution, long after the coal that powered it was burned. The Industrial Revolution represented a revolt against the myth of the idyllic countryside.

Spatial equity. With regard to spatial equity, there is a widespread assumption that there should be a close balance between the benefits and risks from any technology for the communities affected. This is completely contrary to our society as it now exists: What we try to achieve is some rough overall balance. For instance, airports and refineries benefit many who dwell remote from their risks. We who live on the Canadian-Shield part of Ontario recognize that we depend to a large extent on the industrial and agricultural activities of Southern Ontario, which in turn depend on adequate electricity.

Some argue that communities in Northern Ontario should not accept a nuclear-waste repository because it would have a finite operating life. By this argument there should be no mines. A significant difference between a repository and a mine is that the former *could* constitute the basis for a future fuel-recycling industry. This option is not currently being proposed and would require a separate environmental impact statement and regulations, but it could represent an attractive opportunity for some mining communities. Any way of earning a living involves some risk and it is the proponents' contention that work in the Canadian nuclear fuel industry is less hazardous than traditional occupations in Northern Ontario such as mining and forestry. Inhabitants of Elliot Lake have lobbied the provincial government to direct Ontario Hydro to buy more of its uranium from there, so that they may continue mining uranium. Proponents maintain that operating a nuclear waste repository would be at least as safe an occupation as mining. It would be unethical to *deny* Elliot Lake the opportunity to bid for a nuclear waste repository.

It has been suggested that communities should be able to veto the transportation of nuclear wastes through their jurisdictions. This too is contrary to accepted practice and law which permit the free passage of any cargo within existing regulations, even potentially dangerous ones such as gasoline and explosives destined to mines in Northern Ontario. The worst example of spatial inequity is the "NIMBY Syndrome" (Not In My Back Yard) – "I want the benefits but none of the risks." It was to prevent this human tendency blocking a solution to the nuclear-wastes problem that concept assessment was separated from site selection. Pressure by some opponents of nuclear energy to recombine these phases should be resisted.

Import used fuel? Opposition to importing fuel wastes raises an interesting point of ethics. If the EARP Panel were to judge the disposal concept developed by AECL to be conditionally acceptable, e.g., safe only in certain stable geological structures such as the Canadian Shield, would it not be unethical to refuse wastes from countries such as Japan and the Netherlands? Again the conclusion depends on the facts. This issue is similar in principle to the one of spatial equity concerning locating a repository in Northern Ontario.

Conflict of interest for AECL? Some critics of AECL's disposal concept have argued that AECL's research arm should not be responsible for proposing the concept, since its engineering arm, which designs and markets the CANDU power reactor, could benefit from approval of the concept. This view would be contrary to the widely accepted principle that any industry should be held responsible for developing the means for safe disposal of the wastes it produces. In this way, the developer is motivated to find a solution. Some of the U.S.'s problems in nuclear waste management can be attributed to its Federal Government assuming this responsibility, thereby relieving the industry of it.

Insist on the best available technology? By insisting on the best, when it is not necessary, we would be misusing limited resources. We would, in effect, be devoting this generation's resources to saving a few lives over the next million years when the same resources, applied more wisely, could save many more lives much sooner. Also, experience indicates that most life-saving measures, once introduced, are continued, thereby indirectly benefitting future generations. Our "morality" has us ignoring a dying man's present plight as we put money in the bank for his unborn descendants. There is an even more pernicious effect of this unrealistic drive for zero risk. According to Wilson[7], it is counter-productive in that it "creates an incentive for ignorance, not an incentive for safety. Under this procedure if we do not know whether something is risky and close our eyes to the possibility of risk, no one will bother us. On the other hand, if we look carefully and find there is a risk – even though it is small – some regulatory agency may stop us." I hope that anyone assessing the adequacy of the proposed concept will also consider whether it is excessive in view of alternative means of devoting society's wealth to saving lives.

"It's not that people know too little – It's that they know too many things that just ain't so." - *Mark Twain.* Finally, any discussion of the ethics of nuclear energy should examine the ethics of its critics. Most would agree that making false or misleading statements is unethical, whoever makes them. However, different standards apply to proponents and critics: If the Canadian nuclear industry had made as many false or misleading statements in its four-decade history as its critics have just in the submissions to the Scoping Hearings of the current EARP Panel it would be thoroughly discredited and its members' reputations ruined. Proponents are accountable, critics are not. More reprehensible are unsubstantiated accusations and implications, especially when the rebuttal is available to anyone taking the trouble to look. So much relevant information is published that one can sympathize with those who cannot find what they seek, but not with those who cry "Secret!" without even asking. Anyone making an accusation of secrecy should be required to state what information had been denied, by whom, and why. Yet more despicable are those who use scare-mongering tactics, without checking their facts, to advance their views on energy policy. Some critics of nuclear energy are trying to effect social and political change surreptitiously under the guise of energy policy. That, I submit, is unethical. According to William Blake:

"A truth told with bad intent
Beats all the lies you can invent."

Conclusion

Ethics is a personal matter. With over forty years experience in the nuclear industry, and having examined the subject from an ethical standpoint, I have reached my own conclusion that for many applications nuclear energy is the energy source of ethical choice.

Not only the proponents and critics of nuclear energy have a responsibility to examine the ethics of the technology: Regulatory and quasi-judicial bodies also bear a heavy responsibility. I submit that, if my conclusion is valid, it would be *un*ethical to deny a beneficial and benign energy source to this and future generations. For this reason, the ethics of nuclear energy should be examined explicitly, not taken for granted.

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Oldest AECB minutes made public

(reprinted from AECB Reporter)

All minutes of the meetings of the Atomic Energy Control Board going back to 1946, are now available in the Public Documents collection at the Board's Ottawa offices.

In March 1985, the AECB declared that its minutes would henceforth be public documents, and they would be available in both English and French beginning with the set from November 19, 1984. It was noted that the AECB had statutory responsibilities for protecting certain information, so a review of old minutes would be required before their release. Given the interest at the time, a review was done on minutes from the 10 previous years, and those recent-history records were soonn available.

The review of the remaining minutes from the 1964-74 period was recently completed.

Board minute trivia

- the first Board meeting, which started on October 16, 1946, was also its longest. It stretched over three days, involved a trip to the "Chalk River project" and an evening session in Deep River that went on until 12:45 a.m.;
- the AECB's initial budget, not counting funds for operating the Chalk River project, was $50,000;
- in 1947, the lowest paid AECB employee was the Confidential Messenger, at $1,500 per year. The highest paid, at $8,000 a year, were the Scientific Adviser/Assistant to the President, and the Legal Adviser/Secretary to the Board;
- in its first two years, the Board occasionally met on Saturdays;
- the shortest minutes, each of only one page, were recorded on May 24, 1948, and June 4, 1955;
- in its role as overseer of the Chalk River project, and in the interests of the well-being of workers' families there, the AECB contributed a $30,000 grant to build the Wylie Separate School in 1949;
- in the 50s and 60s, uranium was often discussed under the heading "raw materials";
- all Board members appear to have resigned in June 1958, to permit the Minister freedom to act in a reorganization, if he wished (there was no follow-up mentioned, but all members were back at the next meeting);
- in 1958, the Board dealt with a proposal to use a nuclear explosion in the Alberta oil sands; a year later, there was a discussion of a U.S. proposal to build a harbour in Alaska by exploding a number of thermonuclear bombs;
- from October 1958 until the end of 1967, the Board attempted to play an information clearinghouse role, and had representatives from other government departments, agencies and corporations attend its meetings and submit reports;
- in 1964, what is now known as the Pickering Nuclear Generating Station was being referred to as the Fairport site;
- the Board maintained an office at the Chalk River site until 1967;
- the minutes were classified "secret" until March 23, 1972 (they were declassified as part of the review process);
- the AECB's public information head, Hugh J.M. Spence, who was also the Board's recording secretary from 1981 until last year, has the distinction of having two close relatives mentioned in the minutes: his father, metallurgist Neville S. Spence, was noted as a new member of the Reactor Safety Advisory Committee in February 1966, and his grandfather, mineralogist Hugh S. Spence, submitted a report to the Board on beryllium sources in July 1947.

At present, these "historic" minutes are on paper but will eventually be transferred to microfiche.

1992 Third Annual Waste Management Seminar

Ontario Hydro's Safety and Environment Department is sponsoring and hosting this annual event at the Sheraton Toronto East Hotel, on October 19-21, 1992. The scope of the Seminar covers various aspects of solid radioactive and inactive waste management. The emphasis will be on waste management issues facing CANDU nuclear stations. The program will also include presentations from the CANDU Owners Group (COG) as well as station tours and workshops.

For further information, call Ray Bielaskie at (416) 506-7666 or FAX (416) 506-7066.

Ontario Hydro's Demand/Supply Plan Hearings

(Ed. Note: For over two years Ontario's Environmental Assessment Board has been conducting a Hearing on Ontario Hydro's Demand/Supply Plans. Following is an extract from an update report prepared by Ian Wilson of the CNA.)

Introduction

The Ontario Hydro Demand/Supply Plan Hearing began in April 1991 with the presentation of Hydro's evidence. It took until June 1992 for Hydro's ten witness panels to present their evidence and undergo cross-examination.

The original DSP presented included provision for a large number of nuclear units to be constructed in the period 2002 to 2014. In January 1992 Hydro produced an "Update" to the DSP in which the date for major new supply was revised to 2009 mainly on the basis of greater expectations of what could be achieved from Demand Management and Non-Utility Generation, and by planning to meet only the medium load forecast rather than the upper. Hydro advised the EAB that, in view of the Update, approval to proceed with planning for major new supply was no longer being sought.

This attempt to remove consideration and approval of major new supply was opposed by a number of parties to the hearing, including CNA and AECL. The EAB issued a decision that Hydro could not remove its previous evidence from consideration and that the Board retained jurisdiction to approve any of the plans originally submitted.

A further attempt by the CEG (Coalition of Environmental Groups) to remove nuclear from consideration, on the basis that Hydro had failed to submit sufficient evidence on waste disposal and decommissioning, was also rejected by the EAB. The EAB agreed with the position taken by AECL and CNA that the environmental evidence is not complete until evidence from all parties has been heard. The EAB also decided that it would not be constrained by the fact that a waste disposal process has yet to be approved, but did indicate that it would be interested in receiving a general overview of the proposed concept.

The pro-supply groups, originally intervening in support of Ontario Hydro's DSP, now find themselves in the position of advocates for major new supply. The CEG is now on the same side of the table as Ontario Hydro. This has increased the resources which the pro-supply groups must now expend in an effective intervention.

The question remains as to what the nuclear industry can hope to achieve by continued involvement as parties to the Hearings. Clearly the EAB can approve a plan which calls for immediate steps to be taken towards commitment of major new supply including nuclear. On the other hand it is equally clear that Hydro cannot be forced to proceed with planning new supply.

It would be extremely difficult, however, for Ontario Hydro and the provincial government to ignore the findings of a two year public hearing costing about $100 million. It would provide tremendous ammunition to industry intervenors and opposition parties to attack Hydro and the government for making a mockery of the Environmental Assessment process.

The industry has a large investment in these hearings. A positive outcome could ensure the continued development of Canada's domestic nuclear program. Abandonment of involvement would help to ensure the very opposite result.

Intervenor Evidence

From the outset of the hearings, the CNA adopted a policy of full cooperation with like-minded intervenors and, where possible, has shared the cost of intervention with AMPCO (the Association of Major Power Consumers In Ontario). In continuance of that policy, meetings have been held over the summer to discuss the extent of the evidence which pro-supply groups are planning to submit.

It has been agreed that MEA will cooperate with AECL in bringing forward evidence on Demand Management which will cast considerable doubt on the probability that Hydro's very ambitious targets can be met. AMPCO will be working with EEMAC to bring in an expert to criticize the Update by showing its much greater level of uncertainty compared to Hydro's original plan. AECL also plans to bring evidence on reactor safety, waste management and disposal, and plant costs, with particular emphasis on the CANDU-6 which was not extensively covered in Hydro's evidence.

In meetings with nuclear industry groups including OCI, AECL, CNS, SPEA, and CNA, attempts have been made to agree on the thrust and scope of each party's intervention. The CNA has played a coordinating role with the objective of avoiding duplication while at the same time trying to ensure that nothing is allowed to fall through the cracks.

From all of these discussions we have identified two specific topics on which CNA should consider bringing evidence. The first is in the area of public opinion. Polls conducted for the CNA as part of the PIP program show relatively strong support for nuclear, particularly as compared with burning fossil fuels. And there is a very large majority in Ontario who accept that nuclear energy will be important for meeting the province's future energy needs.

The second is the issue of uranium mine tailings. Ontario Hydro made no attempt to deal with the environmental effects of tailings. It would be our intention to bring evidence with respect to the licensing process rather than deal directly with the arguments of anti-nuclear intervenors.

Perhaps an even greater challenge during the remainder of the hearings will be to organize an effective cross-examination of the evidence of the many intervenors who will be submitting the results of the "research" for which they were provided funding. We will only learn the extent of that challenge after we have defined the extent of our own intervention. It is impossible to estimate the extent of this exercise.

Finally, there will be the opportunity to present final argument. Again until we know the full extent of intervenors evidence it is impossible to predict the magnitude of this task with a high degree of accuracy.

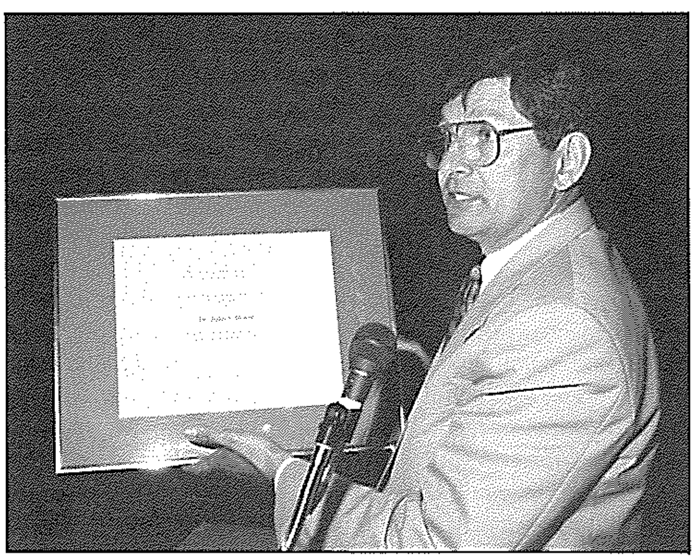
CNS President Bill Midvidy presents certificate to George Howey recognizing his election as a Fellow of the Society at the CNS Annual Conference, June 1992.

CNS Fellowships Awarded

Three pioneers of the Canadian Nuclear Society were named Fellows of the society at the Annual Conference in Saint John in June.

The Fellowship winners, George Howey, Phil Ross-Ross and John Hewitt, were all former presidents of the CNS. George Howey was the founding president, in 1980-81, Phil Ross-Ross followed for two terms, 1981-82 and 1982-83, and John Hewitt succeeded him in 1983-84.

All three were involved beyond their terms as president. They were all members of the organizing committee that steered the formation of the Society in 1979. Phil Ross-Ross drafted the initial policies and procedures while John Hewitt was the key figure in launching the CNS *Bulletin*.



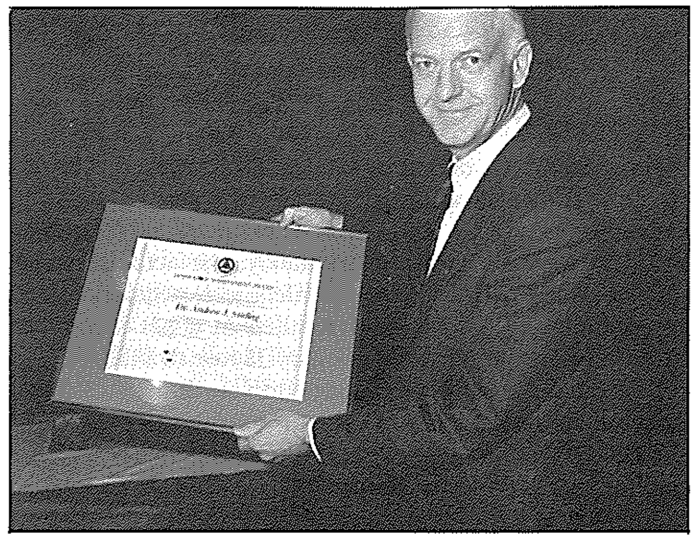
John Hewitt displays the certificate presented to him on being named a Fellow of the Canadian Nuclear Society, at the CNS Annual Conference, Saint John, 10 June 1992.

CNS Innovative Achievement Award

The CNS Innovative Achievement Award for 1992 was presented to Andrew Stirling and his group at AECL Accelerators in Kanata, Ontario.

AECL Accelerators has developed the successful IMPELA line of industrial accelerators and, earlier this year, installed the first commercial unit, in the USA.

This award was presented for the first time in 1991.



Andrew Stirling, general manager of AECL Accelerators, holds plaque that accompanies CNS Innovative Achievement Award, presented at the CNS Annual Conference, Saint John, June 1992.

Community Outreach

All CNS members in Canada should have received, in September, a letter from the president, William Midvidy, soliciting their support for, and involvement in, a new "Community Outreach Program" proposed by the Canadian Nuclear Association.

Assuming there is sufficient support from CNA and CNS members, a detailed program will be developed with a focus on participating in discussions, presentations, exhibits, etc., involving different groups at the local, regional and national levels. The objective is to reach a broad consensus on the future of nuclear power in Canada.

CNS members should mail or FAX the survey form enclosed with the letter to the CNS office (FAX 416-979-8356). If you have not received the letter (or, possibly, misplaced it) you can contact the CNS office (tel. 416-977-7620) or Bill Midvidy (416-592-5543).

Annual General Meeting

The 13th Annual General Meeting of the Canadian Nuclear Society was held Tuesday morning, 9 June 1992, during the CNA/CNS Annual Conference in Saint John, New Brunswick.

As might be expected with a starting hour of 8:00 a.m. there were only a few members present.

The meeting followed the typical agenda – minutes of the previous AGM in Saskatoon, reports from the out-going president, treasurer, and a number of committee chairmen, and a short address by the incoming president. Ironically, with the press of the agenda and the brief time allotted, the formal acclamation of the officers and council members presented by the Nomination Committee was almost overlooked.

The financial statement for the fiscal year ending 31 January 1992 is presented elsewhere in this issue. Copies of the reports from the Treasurer, Education and Public Affairs Committee and the Membership Committee follow.

Treasurer's Report

We had forecast a deficit of some $37,000 at the beginning of the year, based on anticipated revenues of $64,000 and expenditures of $101,000. The actual expenditures totalling $103,054 were on target. Fortunately, the actual revenue totalled $106,661 (mostly from conferences) which exceeded expectations by $43,000 and resulted in a net income of $3,607. So our surplus as of January 31 rose to $158,678.

We did not transfer any money into our Education Fund last year, so the Education Fund surplus remains unchanged at $12,000.

Our total surplus on January 31 was $170,678 of which $133,384 was in short-term investments (Sun Life Trust) at an average interest of 7.5%.

This year, we incurred a one-time cost of $7,800 to upgrade our computer systems for membership records, mailings and invoicing.

The CNS membership fee has remained unchanged for several years, even though costs have been escalating. Although our principal source of revenue is organizing and running successful conferences, it may be necessary to increase the membership fee next year to help cover expenses. This will be taken into account in the planned adjustment of our fiscal year (and the CNA's) to correspond with the calendar year.

Jerry M. Cuttler

Education and Public Affairs Committee

Recognizing the linkage that exists between CNS public affairs activities and public education issues, the CNS Council created the Education and Public Affairs Committee to better focus the activities of the previous Public Affairs and the Communications Committees and to remove the ambiguity associated with their respective mandates. These committees were subsequently dissolved. The new Committee met for the first time on January 30, 1992.

The Terms of Reference for the Committee are:

- To facilitate the exchange of information pertaining to nuclear-related issues amongst CNS members and the general public and to develop and administer educational programs in this regard.
- To encourage CNS members to become involved in speaking out on nuclear issues and to participate in public education programs
- To improve the means by which the CNS communicates with the public.
- To represent the CNS on the CNA/CNS Education and Human Resources Committee.

Speaker Program for High Schools

On February 21, 1992, members of the Committee met with both the separate and public school curriculum coordinators for the Halton Board of Education to discuss possible topics of relevance to the school program. This approach was identified by Troy Lassau (who serves as a trustee on the Halton Board) as being the most appropriate in terms of gaining acceptance in the schools. Our goal was to address the needs of the school system and develop a speaker package to satisfy their curricula requirements.

A meeting is now being arranged with the science department heads of the Halton School Boards to discuss a pilot speaker program, beginning in September 1992 which will satisfy elements of the high school science curricula.

One member of the committee, Dr. Jerry Cuttler, has spoken at a number of school functions in the past several months (see Vol. 13, No. 2) of the CNS *Bulletin* for writeup). An article was also written in the CNS *Bulletin*, appealing to the CNS membership to get involved in the program to speak to high school students. A number of others have responded.

Education Fund

The committee is also tasked with the administration of the CNS/CNA Education Fund, which allows each CNS Branch to apply for up to $1000 per annum for Branch education programs. This year, $3000 was granted to the Chalk River, Ottawa and Saskatchewan Branches. This money was used to send a teacher to the "Science for Educators" Program, to support two students in attending the Deep River Science Academy (2 awards of $500), and to support the Saskatoon Regional Science Fair (awarded as a travel bursary to allow regional science fair winners with energy-related exhibits to attend the national science fair).

CNS/CNA Education and Human Resources Committee

Because of the CNA reorganization this year, this committee did not meet during the year 1991-1992 session. Recently, however, there have been efforts to revive this committee. Last year, a Careers Brochure was drafted, featuring young engineers in the nuclear field. The draft of this brochure was recently finalized, after locating a fourth candidate, a female engineer in the uranium mining industry. In the next several months, the committee will attempt to locate funding partners to produce this brochure for distribution to high school students.

Shayne Smith

Membership Committee

Paid-up membership continues to increase:

	1992 June	1991 June	1990 June
Charter	84	89	
Regular	519	429	
Institutions	7	8	
Students	43	32	
Retired	44	32	
	697	590	528

We have attracted 122 new members since 1991 September 1.

Eighty-five members did not renew and their names are being deleted from our mailing list.

We have a problem with membership renewal. 163 still had not paid their fees after the second letter, so we asked each branch president to help and this resulted in 78 more people renewing.

This year we distributed CNS pens to new and renewing members. (Last year, coffee mugs were provided.) In addition, we are presenting a CNS tie to each person who brought in new members.

The respondents to last year's membership questionnaire were satisfied with our communication and our program. A large majority would like greater CNS involvement in public acceptance.

Last year we asked the AECB to permit their employees to join. The AECB responded that membership of their employees in the CNS would create an apparent conflict of interest due to our affiliation with the CNA.

We must continue to raise the profile of the CNS. There are many potential members in the industry and the public. We must all continue promoting membership at all our events.

Jerry M. Cuttler

Council for 1992-93

The following list of officers and members of the Council of the Canadian Nuclear Society was acclaimed at the Annual General Meeting held Tuesday, 9 June 1992, during the annual conference at Saint John, New Brunswick.

President: Dr. W.I. Midvidy, O.H.
Immediate Past President: Dr. G.J. Phillips, Fusion Canada
First Vice-President: Dr. P.J. Fehrenbach, AECL Research
Second Vice-President: Mr. E.G. Price, AECL CANDU
Secretary: Dr. B. Rouben, AECL CANDU
Treasurer: Dr. J.M. Cuttler, AECL CANDU

Other members:

Mr. S. Smith, Wardrop Engineering
Mr. T. Lassau, ORTECH
Dr. H.W. Bonin, RMC
Mr. J. Sobolewski, AECL CANDU
Dr. O. Akalin, O.H.
Mr. H.M. Huynh, H.Q.
Dr. V.S. Krishnan, AECL Research
Mr. S. Kupca, AECL/DND
Mr. M.A. Lone, AECL Research
Dr. D. Rozon, Ecole Poly.
Mr. K.L. Smith, UNECO
Mr. P.A. Ross-Ross, retired.

Officers' Seminar

The annual Officers' Seminar was held September 30 in Toronto. This is the time when officers of branches meet with the CNS Council to discuss mutual problems. Five branches were represented.

CNS officers for 1992-93, l.-r.: Ed Price, Gil Phillips, Bill Midvidy, Paul Fehrenbach, Ben Rouben, Jerry Cuttler.

Report from Outgoing President to Annual General Meeting

by Gil Phillips

The CNS has had a successful, and relatively uneventful year. Other Council members will be reporting on their specific areas, so this will be a brief overview.

Membership continues to grow, slowly but steadily. The Society is on sound financial ground with a healthy bank balance, in spite of the state of the economy and its effects on the Canadian nuclear industry.

We currently have ten branches, and as usual there is a spectrum of activity, from the perenially busy Toronto Branch to some that at the moment show few vital signs. These will be challenges for future Councils. I would like to particularly mention the Chalk River Branch, which has undergone a renaissance in recent years, and this year has produced some program innovations. These will be described to you later.

Our continuing financial health depends strongly on a supply of conferences that appeal to the nuclear community, and our Divisions have been successful in stimulating such events.

On the international scene, we are participating in the International Nuclear Societies Council, a relatively new umbrella organization that we expect will be of increasing importance on the world scene.

This year we have made a start on an integrated Student Exchange Program with the French Nuclear Society, and we have also been invited to begin a similar arrangement with the American Nuclear Society.

On more local matters, we have created a new category of membership in the Society, and you will hear more of that later.

The *Bulletin* continues to be an attractive, interesting and effective journal, due almost entirely to the dedicated efforts of its Editor.

The CNA/CNS offices were re-located this past year, and our Society is benefitting from the improved facilities. We continued to enjoy excellent relations with the CNA.

For the future: the incoming Council will be heavily involved in the presentations for INC 93, which should be a very exciting event. The CNS is responsible for the technical program, and we hope to involve many of you in this task.

I've enjoyed my year as President, because I've had an excellent Council working with me, and I'm very grateful for their dedicated efforts. The incoming Council will be equally effective, and I'm sure that the Society will continue to flourish.

The 17th Annual Simulation Symposium

The 17th Annual Canadian Nuclear Society Symposium on Simulation of Reactor Dynamics and Plant Control was held in Kingston, Ontario, August 17 and 18, 1992.

Successfully hosted by the Royal Military College, the activities started on Sunday, August 16, with a get-together evening with wine and cheese at the Holiday Inn in downtown Kingston. At 0850 sharp the next morning, the Commandant of RMC, BGen Jean E.J. Boyle, officially welcomed the participants to the Symposium, and offered apologies for the disturbance due to the intense construction activities under way all over the Campus. The most spectacular construction site was at the clock tower of the old MacKenzie Building, which was having its top rebuilt after being hit by lightning about a year ago. At 0900, the sessions were under way and a total of 30 papers were presented over the two days, in seven sessions in thermalhydraulics, five sessions in reactor physics and one session in containment analysis.

A total of 62 participants were registered, with a strong participation from AECL-CANDU and École Polytechnique. One of the activities of the Symposium was a tour of the SLOWPOKE-2 Facility at RMC. A formal dinner was held at the Senior Staff Mess and Dr. Daniel Meneley, Corporate Vice-President of AECL, entertained the participants with an excellent presentation on the safety of the Eastern European nuclear reactors.

The pace of the Symposium was kept a bit more relaxed than for ordinary conferences, and the extra time for discussion was obviously well appreciated by all. Most of the full papers were on hand and ready to be inserted in the Proceedings binders. The few still missing will be mailed to the participants within a month or two. Additional copies of the Symposium Proceedings are available at $30.00 a copy (+ GST) from the office of the CNS in Toronto.

This 17th Symposium was once again successful, and the Call for Papers for the next CNS-organized conference has already been issued. In 1993, the Symposium will be replaced by the Fourth International Conference on Simulation Methods in Nuclear Engineering, 2-4 June 1993, in Montréal, Québec.

Hugues W. Bonin

Canadian Nuclear Society Financial Statements • January 31, 1992

Auditors' Report

To the Members of the Canadian Nuclear Society

We have audited the balance sheet of the Canadian Nuclear Society as at January 31, 1992 and the statements of operations and surplus and education fund for the year then ended. These financial statements are the responsibility of the Society's management. Our responsibility is to express an opinion on these financial statements based on our audit.

We conducted our audit in accordance with generally accepted auditing standards. Those standards require that we plan and perform an audit to obtain reasonable assurance whether the financial statements are free of material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation.

In our opinion, these financial statements present fairly, in all material respects, the financial position of the Society as at January 31, 1992 and the results of its operations for the year then ended in accordance with generally accepted accounting principles.

Toronto, Ontario
May 21, 1992

Doane Raymond Pannell
Chartered Accountants

Balance Sheet • January 31, 1992

	1992	1991
ASSETS		
CURRENT		
Cash	$ 88,998	$ 41,435
Accounts receivable	20,922	61,519
Prepaid expenses	—	1,000
Short term deposits	133,384	82,861
	243,304	186,815
CNS share of education fund assets (Note 2)	12,000	12,000
	$255,304	$198,815
LIABILITIES		
CURRENT		
Accounts payable	$ 2,475	$ 13,849
Payable to CNA	62,369	9,823
Membership fees and contributions received in advance	19,782	8,072
	84,626	31,744
EQUITY		
Surplus from operations	158,678	155,071
Education fund surplus (Note 2)	12,000	12,000
	170,678	167,071
	$255,304	$198,815

See accompanying notes to the financial statements.

Statement of Operations & Surplus Year Ended January 31, 1992

	1992	1991
INCOME		
Membership fees	$ 33,995	$ 31,565
Publications	5,638	9,511
Interest	14,985	12,957
	54,618	54,033
SOCIETY PROJECTS		
Excess of income over expenditures		
Annual conference	31,649	33,218
Nuclear simulation symposium	10,306	—
'89 CANDU fuel conference	—	(224)
CANDU chemistry seminar	2,143	4,335
Containment design & operation conference	258	28,261
Steam generator & heat exchanger conference	568	28,234
Simulation methods conference	—	21,417
Neutron radiography conference	5,908	2,653
Fusion seminar	1,211	—
	52,043	117,894
	106,661	171,927
EXPENSES		
Contribution to education fund (Note 2)	—	3,000
Office overhead charge from CNA	30,000	21,000
Office services	27,895	18,652
Canadian Nuclear Society *Bulletin*	18,291	18,204
INC'93 feasibility study	—	10,000
Branch activities	(501)	2,691
Membership committee	8,820	4,709
Program committee and technical divisions	1,697	4,368
Stationery and printing	4,181	6,006
Council activities and promotion	3,161	500
Students' conference	3,799	1,500
Officers' seminar	—	220
Innovative Achievement Awards	5,711	—
	103,054	90,850
Net income	3,607	81,077
Surplus, beginning of year	155,071	73,994
Surplus, end of year	$158,678	$155,071

Statement of Education Fund • Year Ended January 31, 1992

	1992	1991
Surplus, beginning of year	$ 12,000	$ 9,000
Contributions – Transfer from operating fund	—	3,000
Surplus, end of year	$ 12,000	$ 12,000

See accompanying notes to the financial statements.

Notes to the Financial Statements • January 31, 1992

1. SIGNIFICANT ACCOUNTING POLICIES
   (a) **Revenue Recognition**
   - Membership fees are included in income in the fiscal year to which they relate.
   - Interest and other income is recorded on the accrual basis.

   (b) **Short Term Deposits**
   - These investments are carried at cost plus accrued interest.
2. EDUCATION FUND

From 1988 to 1991, annual contributions amounting to $3,000 from the Society and $7,000 from the CNA were allocated from the income from the annual conference. The interest on these funds is available for educational purposes to the local branches of the Society. The principal remains the property of the CNA and the Society.

The total fund is composed as follows:	1992	1991
Principal contributions		
CNA	$ 28,000	$ 28,000
CNS	12,000	12,000
	40,000	40,000
Accumulated interest available to CNS local branches	11,725	7,351
	$ 51,725	$ 47,351

New Members

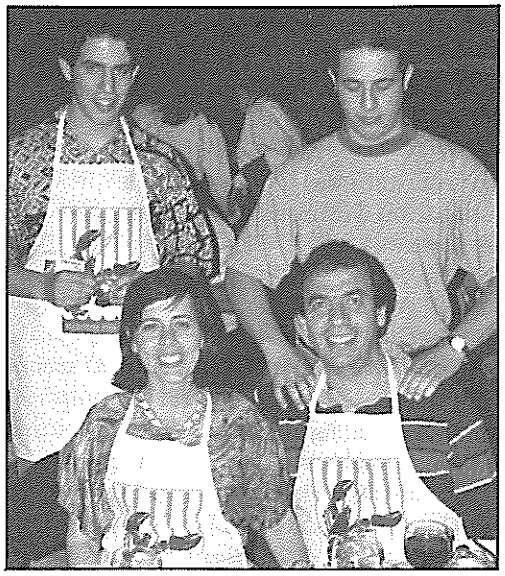
Following is a list of new members since September 1991.

It is possible that the list includes names of persons who have been members in the past. If someone's membership lapses and then, later, is renewed, the computer interprets that as a new membership.

Kasem N. Abotel*/**
Alan John Adams
Ernest Aikens
Roger P.M. Ainley
Tim Andreeff
Benoit Arsenault**
Ibrahim Attijeh
M.R. Balakrishnan**
Tibor Sandor Balint
Edward H. Bassett
Alfio M. Bazzichi**
J.A. Beadle
Paul Bekeris*
Barrie Bergsma
C. Bruce Bingham
Gerard V. Bischoff
Andre G. Bouchard
William T. Bourns
Denis Brissette
Krzysztof Buettner
Jan V. Burnham
Pratondo Busono*
Eric V. Carruthers
In-Hwan Cha**
Serge Chapados
Jan G. Charuk
Brian A. Cheadle
Rhonda J. Cheadle
Pu Chen*
Larry Christie
Christopher Coleman
Roy Colquhoun
J. Georges Comeau
Ken D. Cotnam
Gregory Cripps*
Walter G. Davies
Morley W. Davis
Eric De Souza
M.A. (Tony) de Vette
Dan J.G. deVerteuil
Rob Dewar*
Chong Yu Ding*
Suzie el-Saadany*
Dewi G.S. Evans
Vern W. Evans
Jimmy Farley
Lou Fernandes
George J. Field
Egon R. Frech
Peter R. Frise
Nelson Garceau
Maya C. Garisto
Frank Giudice
Domenico Giusti
Andrew S.R. Godo
Richmond E. Graham
Juris R. Grava
Stuart Groom
Patricia Guenkel
Parviz Gulshani
Stephen C. Hahn*
Khalid Hamsad*
A.M.I. Hague**
Ralph S. Hart
Lyndell D. Hastings
Damir Hegedus
Vlad Hera
A. Douglas Hink
Ryan Hinz
Wilfrid A. Hinz
Bill Holtslander
James R. Hopkins
Terry Howe
Leonard Ing
Brant Jacklin
Rafael Janica*
Alan Thomas Jeffs
Natalie Ilze Kanbergs
Robert E. Keen
Ricky Khaloo*
Roger Otto Kleegaum
Raphael Koujoumadjian
Stephen M. Kuchurean
Emelie S. Lamothe
Fued F. Langford
David E.A. LeFrançois
David Lenihan
Frances A. Lipsett
John J. Lipsett
William Liu
Khaled Mahdi*
John J. Marchildon
Peter Marchok*/**
Guy Marleau
Henri Marois
Henry A. Martin
Edward F. Marwick
Milad Matthias
Kenneth D. McDonald
David S. McDougall
Diana C. McElroy
Joseph McKeown
Brian V. Mech*
Victor A.W. Middleton*
Moaied M. Miften
Deborah L. Moir
Derek N. Mori
Alan R. Morrish
Javad Mostaghini
Saeideh Mousavi Yeganeh**
Eric Murray*
Ajit Muzumdar
Chi Hieu Nguyen
Douglas A. Nicks
Jennifer Noronha
William Z. Novak
Izundu Obinelo*
Allan Ouellet
John Pauksens
Guy M. Pepin
Marc-Antoine Petrilli
Lyle Pittman
James L. Platten
Doug Plaxton
Jadranka Popovic
Claude Pothier Jr.
Huguette G. Pothier
Ralph Potts
Elizabeth L. Quarshie
Mirza Ray
Peter P. Revelis*
Rick Ricciuti
David J. Richards
Jack Richman
Andrew C. Rickaby
Christopher Riehl
John L. Robertson
Jeffrey E. Robson
Michel Saint-Denis
Dewanto Saptoadi*
Barbara D. Sawicka
David Schelter*
Henry A. Schnell
Lloyd C. Secord
William C. Shaver
Surinder Singh
Jiri Slaby*
Allan Smith
John Edmund Smith
Francis Su
Roxanne Summers
Bernard Surette
Jacek Szymanski
John Walter Thompson
Heather Turner
Odette Vagner*
Ennio Valente
John A. VanGulik
Jack Veeder
Kalyana Venkatraman
Frank J. Vumbaco
Terry N. Walbaum
Jianwei Wang
Wengming Wang*
Michael J. Ward
Larry Watt
Dale Weeks
Ken Wigley
Duane Wilson
Douglas C. Wright
Shih-Tse (Stan) Yin
Guan G. Young
Wajdi Michel Zoghaib*

* student
** outside Canada

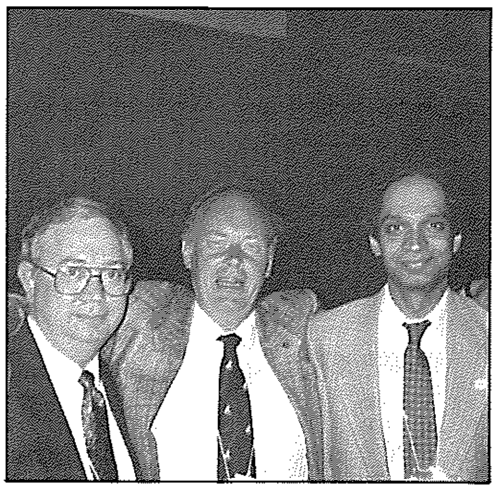
Thirteenth Annual CNS Conference



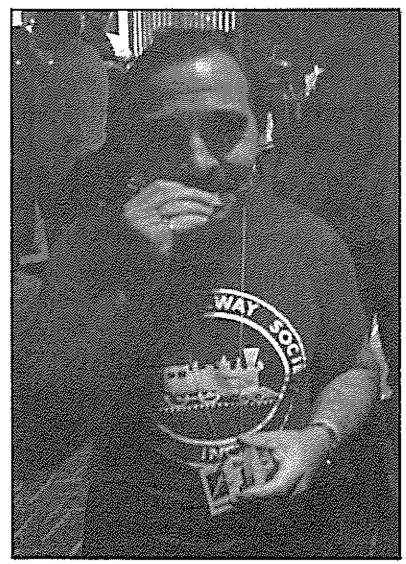
Incoming president Bill Midvidy enjoys lobster fest with family members Rebecca, Daniel and Eric.

Ready to start - delegate kits lined up before registration begins.

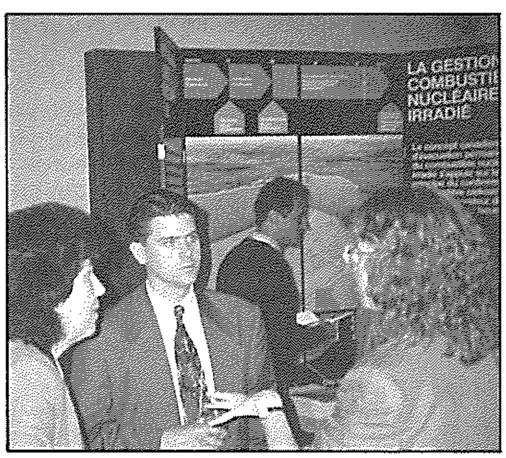
Some of the Chalk River delegation in a deep technical debate.



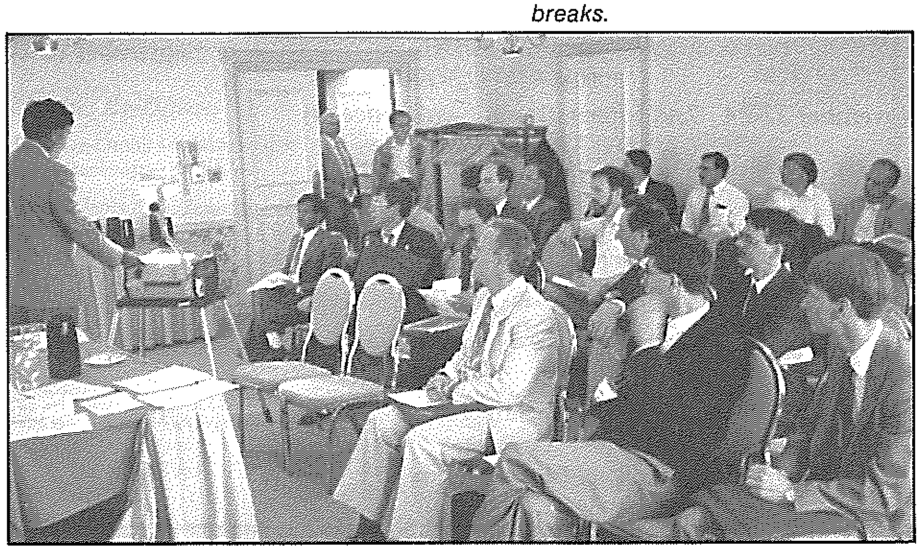
The organizers - Conference chairman Jan Burnham embraces CNS program co-chairmen Keith Scott and V.S. Krishnan.



Former president Hugues Bonin enjoys a snack during one of the breaks.



Education chairman Shayne Smith takes an opportunity to "educate" some teachers at the special Teachers' Seminar.



A typical technical session.

Calendar

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

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

November 15-20 — **ANS Winter Meeting**
Chicago, Illinois
contact: Dr. W.I. Midvidy
Ontario Hydro
Tel.: 416-592-5543
Fax: 416-978-0193

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

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

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

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

1993

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

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

June 2-3 — **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

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

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

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

AECB annual report

(reprinted from the AECB Reporter)

According to the 45th annual report of the Atomic Energy Control Board tabled in the House of Commons in late June, power reactor operation in Canada was acceptably safe. However, it notes there were more than 640 unusual events during 1991 of which more than 180 required a formal report to the AECB.

These events ranged from minor spills of radioactive heavy water to damaged fuel bundles. The AECB requires that, for every significant event, the underlying causes are understood and the necessary corrective actions are taken by the operators. The AECB's licensing system assures that nuclear facilities and materials are utilized with proper consideration for health, safety, security and protection of the environment.

The report points out that of about 6,500 nuclear generating station (NGS) workers who were exposed to radiation, none received a radiation dose greater than the legal limit of 50 millisieverts per year. In fact, no worker received more than 20 millisieverts. Discharges at all plants were found to be very low and resulted in a dose no greater than 0.001 millisievert for residents near the Point Lepreau station in New Brunswick, or 0.02% of the public dose limit of 5 millisieverts. For people at the boundary of Ontario Hydro's Pickering plant, the dose was 0.038 millisieverts or less than 1% of the public dose limit.

The report identifies certain problems at reactor sites, such as:

- difficulties with the reactor fuel at the Darlington NGS;
- boiler tubes on Units 1 and 2 of the Bruce A NGS cracked and leaked, and pressure tubes have shown wear caused by vibrations of the fuel bundles;
- at the Pickering NGS, pressure tubes in Unit 4 are being replaced by Ontario Hydro.

No uranium mine or mill worker was found to have exceeded the maximum permissible radiation dose during the year. At uranium refining and conversion facilities, the estimated dose to the public from emissions was about 0.006 millisieverts or 0.12% of the public dose limit. The average dose received by refinery workers was about 1.1 millisieverts or 2.2% of the occupational dose limit. Although uranium mining activity is down, the AECB referred six new mines for public review by an environmental review panel.

The AECB issued 3,779 licences for the use of radioisotopes in medicine, research, and industry. AECB inspectors carried out 3,052 inspections of licensees and identified 1,358 major infractions that could have affected radiation safety. On the other hand, only minor violations of licences were found during inspections of particle accelerators used in cancer therapy and scientific research.

Copies of the *AECB Annual Report 1991-1992* may be obtained from the AECB Office of Public Information.