CANADIAN NUCLEAR SOCIETY

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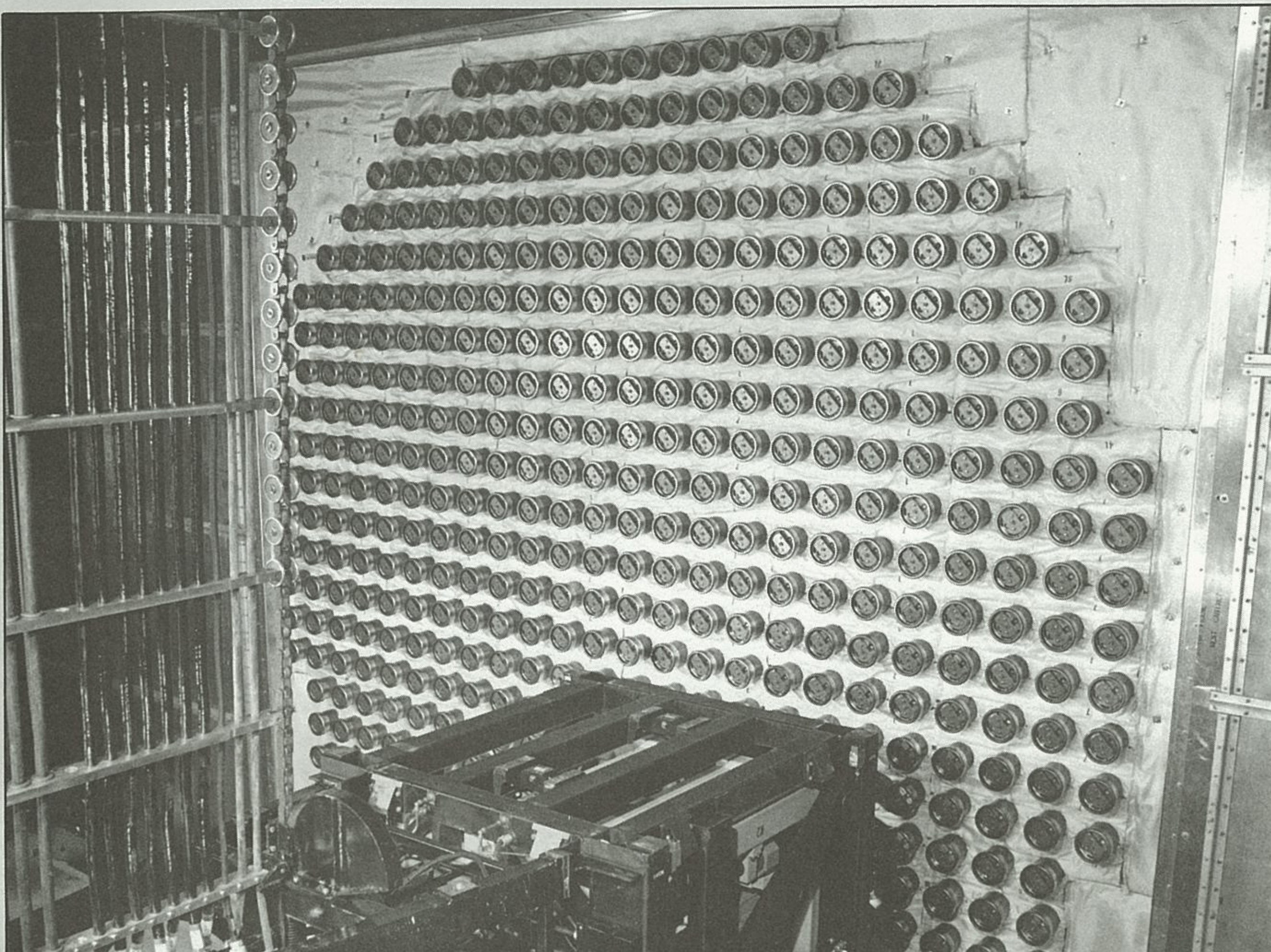

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PRINTED ON RECYCLED PAPER IMPRIME SUR PAPIER RECYCLE

Cover photo

The cover photograph is of a face of a Bruce 'A' reactor showing the endfittings of the many fuel channels – indicative of the large number of rolled joints in a CANDU – as discussed at the International Conference on Rolled and Expanded Joint Technology summarized on page 12.

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

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

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Musings on a Meeting

When you are sceptical about a project from the beginning it is difficult to be objective in reviewing it. That is our problem in commenting on the INC '93 International Nuclear Congress.

INC '93 was in planning for three years, and if the previous conception (the RAMP program) is included, the gestation period was even longer. That earlier concept was to have a great international "dialogue". What eventually evolved was a conference not greatly different from the annual ones of the Canadian Nuclear Association except for more, invited, international speakers and panel participants. Reportedly there were 28 countries represented.

Some of these international experts did present interesting papers or comments during the panel sessions, especially dealing with the world energy scene, problems of large scale financing, and the currently fashionable topics of "social issues and environmental implications". The overviews on the energy and finance scenes, while not new, did provide those not familiar with those areas with some appreciation of that important context. Some delegates felt encouraged that there now appeared to be at least a willingness to enter into true "dialogue" with the "general public". Others had a strong sense of "deja vue", especially in the hand-wringing over the lack of public acceptance of things nuclear.

In all of this "dialogue" there were few, if any, "outsiders", and as indicated at one of the panel sessions, even very few top executives of the nuclear industry.

The total registration of about 500 was respectable but short of the organizers' target. Conspicuous by their absence were representatives of Ontario Hydro (which sent only a dozen people). A registration fee of $800 (excluding a $65 banquet) probably deterred some prospective attendees.

There was an excellent exhibition – the best nuclear show staged in Canada. Unfortunately attendance appeared to be low, possibly attributable to the exhibition hours coinciding with those of the conference sessions.

The technical sessions of contributed papers – organized, by the CNS relatively late in the planning – were interesting and the papers generally of high quality – but they were reminiscent of annual CNS conferences. With as many as six concurrent sessions it was, as usual for such arrangements, frustrating for anyone with interests in more than one subject area.

Many will, undoubtedly, feel that INC '93 was a success. In some aspects it was. But it is unlikely to leave any significant impact on the nuclear scene in Canada or elsewhere and will probably soon be forgotten, even by the participants.

Going Nowhere

The legal battle over the Nuclear Liability Act is one more example of the fruitless, expensive, confrontation that is consuming more and more of our energies.

The Ontario Hydro Demand / Supply hearings cost tens of millions of dollars and achieved nothing. The NLA case could run up costs in the millions – mostly on legal fees – and the outcome will probably have no real effect on the nuclear industry, the supply of electricity, or any other meaningful activity.

Even if the plaintiffs win a partial victory – it is almost assured that they will not win all of their charges – it will only lead to a revision of the Act, probably requiring more commercial insurance. By the time the next Canadian nuclear power plant is committed utilities will likely be able to accommodate that, as experience in other countries has shown.

If, as a country, we continue to expend our energies on such useless endeavours we will never emerge from the economic and social doldrums in which we are now mired.

In this Issue

This may be considered as a "conference" issue and consequently it may appear different than usual.

Much of the content concerns three conferences held over the past few months in which the Canadian Nuclear Society was very much involved.

First there are reviews, prepared by the various session chairmen (chairpersons), of the papers presented at the very successful **International Conference on Simulation Methods in Nuclear Engineering** which was held in June in Montreal (and was reported on briefly in the last issue).

Second is a report on the equally successful **International Conference on Expanded and Rolled Joint Technology** that took place in Toronto in September. Accompanying that report is an excellent overview paper describing the use of expanded and rolled joints in CANDU reactors – the first such review we have come across of this important and critical application.

Finally there are reports on the **INC '93 International Nuclear Congress** in Toronto in early October; including the official review of the conference and a selection of summaries of contributed technical papers (the part of the conference organized by the CNS).

These conference reports are augmented, as usual, with news of the Society and a pot pourri of other items.

As always we welcome your comments, criticisms (even praise!).

INC '93

The International Nuclear Congress and Exhibition called **INC '93** took place in the Sheraton Centre Hotel in Toronto, October 3 to 6, 1993. It began with a typical reception on the Sunday evening and closed Wednesday afternoon with a summary review presented by AECL president Bruce Howe.

About 500 attended the three day conference, including representatives of 28 different countries. Many of the offshore delegates were invited speakers or panel participants – the conference was structured with invited papers in the mornings and panel sessions on the same topics in the afternoon.

In parallel with the invited papers there were concurrent sessions of contributed technical papers, organized by the CNS, in which 110 papers were presented.

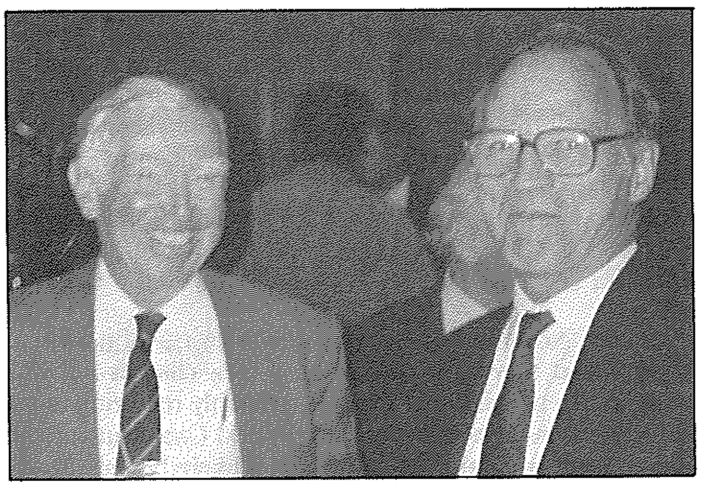
The Monday morning keynote addresses covered the themes followed in the main part of the conference: future energy needs (by Henrik Ager-Hanssen, V.P. STATOIL, Norway); social issues and environmental implications (by James Hann, Chairman, Scottish Nuclear Ltd.); economics and financing (by Robert Skinner, OECD); and technological developments (by Dr. Allan Bromley, former assistant to U.S. President Bush for science and technology).

Later that morning the invited papers sessions delved into waste management and reactor safety, and these topics were pursued in round table discussions in the afternoon.

Tuesday, the invited papers focused on: economics of electrical generation; and "clearing the public acceptance hurdle", again with follow up round table sessions later in the day.

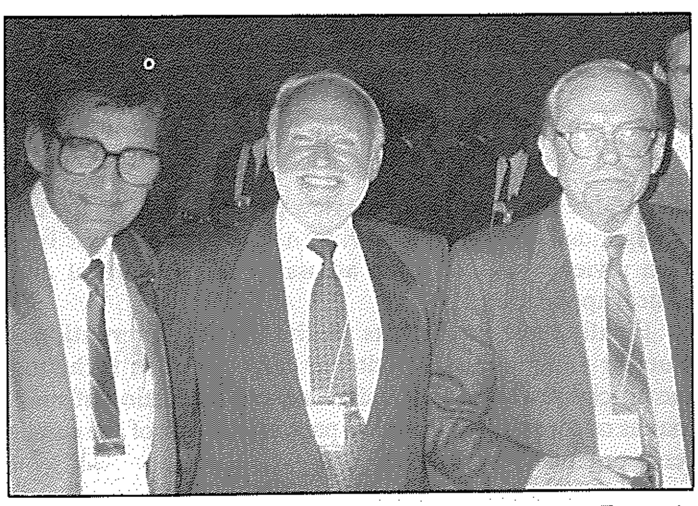
On the Wednesday, the plenary session moved to the afternoon with W. Kenneth Davis, former U.S. Deputy Secretary of Energy and V.P. Bechtel Group, and Prof. Jose Goldenberg, former Secretary of State for Science and Technology, Brazil, tackling the question of "what strategies could meet global energy needs through the 21st century?"

The conference closed with a review and conclusions by Bruce Howe, president and CEO of Atomic Energy of Canada Limited.

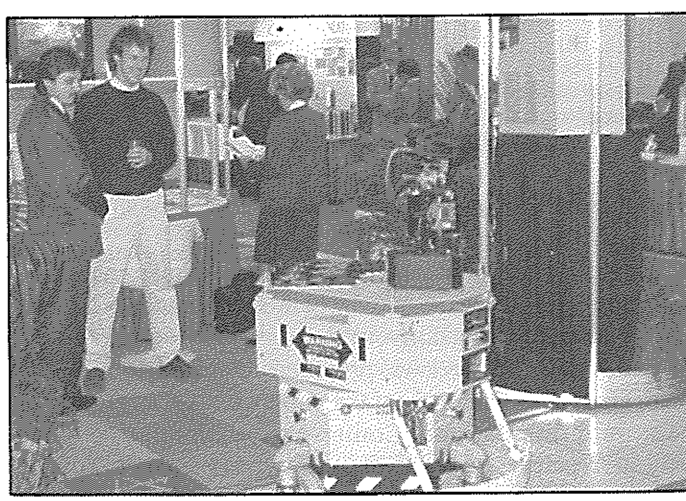


Phil Ross-Ross, a former CNS president, and Terry Rogers of Carleton University, share a joke at INC '93

Delegates cluster around the New Brunswick group of exhibits at the INC '93 exhibition in Toronto, October 1993.



Former CGE colleagues reunite at INC '93. L-R: Walter Tarasuk, Sil Dragon, Bill Brown



A popular feature of the AECL exhibit at INC '93 was this mobile robot

INC '93 Overview

Bruce Howe

Ed. Note: *At the close of the International Nuclear Congress, INC '93, held in Toronto October 3 to 6, 1993, Bruce Howe, president and CEO of Atomic Energy of Canada Limited presented a "Review and Conclusions" of the conference.*

Following is the text prepared for that presentation. Mr. Howe followed the prepared text closely except to add comments on the sessions held by women delegates on the subject of "cracking the glass ceiling," the invisible barrier keeping women from senior positions. Noting the relatively small number of women in nuclear activities he expressed concern about the talent that the industry is missing.

The statement deals almost exclusively with the keynote addresses and invited papers, with little or no reference to the several round table sessions or the excellent technical program organized by the CNS in which 110 papers were presented. It is structured according to themes as perceived by the reviewers rather than the organization of the conference.

Introduction

To summarize the profound and extensive observations and analyses that we have been exposed to in the past three days is a daunting, but pleasant, task. I hope you will forgive me if, in my précis of the proceedings, I omit or understate any of the significant conclusions.

First, let me say that, by any standard, the content of this conference has been excellent. We have been extremely fortunate to hear important perspectives on global energy issues from an array of distinguished international speakers. They have left us much to contemplate as we consider our collective and individual roles in the vital challenge of meeting future energy needs.

In my review I will address the following areas that I believe represent the main themes of the conference agenda. These are:

- Future Energy Requirements
- Economics of Electricity Generation
- Radioactive Waste Management
- Reactor Safety
- Public Acceptance
- Technology Developments
- Future Energy Strategies

I will speak more specifically later on about the sessions on public acceptance. But I want to note at the outset that public acceptance is a common thread which is woven through all the major issues – whether they be economics, reactor safety, the need for energy or nuclear waste management.

Future Energy Requirements

With the world population doubling in the next century, no matter what range of scenarios we envisage, there will be a massive increase in energy needs, mainly in developing countries.

The keynote speakers were either in unison or in close harmony in this area. They agreed that fossil fuels will remain the dominant source of energy well into the next century. Renewable energy sources will not increase significantly, although "new" renewables such as solar and wind power might double to a four per cent share by 2020 – a small, but nevertheless significant, contribution.

Dr. Ager-Hanssen noted that for the period beyond 2020 there is a growing recognition that nuclear and coal will be readily available and will be the major options. He also warned that, despite Rio, there is no realistic possibility, under current policies, that the industrialized countries will contain their greenhouse gas emissions at 1990 levels at the end of the decade.

Dr. Robert Skinner reported on a recent IEA study which predicted a 50% increase in world energy demand by the year 2010, with an increasing dependence on electricity. The study showed the nuclear fraction of the energy mix declining over this period assuming no large increase in fossil-fuel prices.

"Public acceptance depends on public involvement in decision-making."

Professor Goldemberg sees a significant future role for nuclear, certainly remaining at the present level and possibly doubling in absolute terms by 2020. But nuclear will be competitive with fossil fuels only if the nuclear plants are built rapidly and operate well.

Kenneth Davis also sees a necessary role for nuclear in a "practical/realistic vs. ideal" future. But he concludes that it will be extraordinarily difficult to meet our energy requirements in the 21st century, even with the maximum reasonable use of nuclear as well as other realistically available sources of energy.

Economics of Electricity Generation

One key issue that will determine the future role of nuclear energy is that of economics. The underlying messages from the sessions on the economics of electrical generation were:

1) Currently operating nuclear plants are competitive in most regions of the world
2) Future nuclear plants are expected to remain competitive

Korean data, for instance, show that the Total Unit Energy Cost of electricity from PHWRs is currently 27 Won per kilowatt hour, from PWRs 32 Won, from coal 32 Won and from LNG 44 Won.

Using the Levelizing Unit Energy Cost methodology, studies by the Nuclear Energy Agency of the OECD, the National Energy Board of Canada and Natural Resources Canada, show that nuclear power is competitive with coal and gas-fired generation in the OECD countries and will continue to be an appropriate option. Dr. Robert Morrison told us that Ontario's best long-term economic alternative appears to be nuclear generation from a multi-unit station.

Of particular interest is the fact that the economic advantage of nuclear power has deteriorated since the last OECD study, not because of increased nuclear power costs, but because of the decrease in thermal power costs due to lower prices for coal and gas. But the study still predicts an economic advantage for nuclear in most countries. This advantage would increase significantly if fossil fuel prices were to rise in the future. A possibility in this regard would be a tax on carbon-based fuels to reduce air pollution due to greenhouse gases.

These studies clearly show that the economics of nuclear power have remained fairly stable over a decade. This is an important point, because conventional wisdom still assumes that the costs of nuclear power are continuing to escalate as they did in the 1970s. The OECD study shows that this period of cost escalation has ended and that in fact, nuclear power costs are now stable and predictable, thus reducing much of the perceived risk of the last decade.

If the costs are becoming more stable, what then are the challenges of the future?

First, we need to find ways to convince the marketplace of the reduced financial risk. Second, as stated by Mr. Saunders of the World Bank, and Dr. Skinner of the IEA, the main impediment to increasing the share of nuclear power in the developing countries, where electricity growth will be the largest, is access to the capital investment necessary to implement projects of this magnitude. In the industrialized countries, there likely will be the requirement for an improved regulatory regime, for enhancing public participation in the process, and for integration of environmental and energy objectives.

Radioactive Waste Management

There is a clear recognition that public acceptance of nuclear power requires public confidence that radioactive waste and, in particular, nuclear fuel waste, is being, and can continue to be, managed safely. The internationally agreed objectives of radioactive waste management are protection of health, protection of the environment, and the minimization of any burden on future generations. There is public concern about the ability of the industry to meet these objectives, despite the fact that radioactive disposal facilities for low-level wastes are already operating safely in France, Spain, Sweden and Finland.

A common theme emerging from the discussions at the Congress is a realization that geological disposal is the *de facto* international standard for disposal of nuclear fuel. Those countries that practise reprocessing are also looking at the benefits that may be obtained from transmuting some components of their radioactive waste, particularly France and Japan. Even in these circumstances there is a clear recognition that there will be a requirement at some point for geological disposal.

There is an absolute requirement that any agency responsible for carrying out radioactive waste management must demonstrate its commitment to safety. It is a key requirement in addressing public concern, and in nurturing public confidence. Safety must be a paramount consideration in all decision-making. Public review processes are part of ensuring that due attention is paid to safety. Independent review by technical experts and by regulatory authorities also plays an important role in ensuring that operations are safe. But this in itself is not sufficient to convince the public that we are doing the right things in the right way.

Public acceptance depends upon public involvement in decision-making in a real and meaningful manner. Decision-making must be open. The public and its representatives, politicians at all levels, but particularly at the local level, must be involved and be seen to be involved in the decision-making process. Communication needs to be two-way. Other industries are finding that they must learn to listen to the concerns of the public – we also must learn this lesson. This requires that waste management agencies engage the public and deal with them frankly with a commitment to principles of fairness and openness, so that affected communities participate effectively in decision-making and have the power either to accept or reject a facility.

"Nuclear will be competitive only if nuclear plants are built rapidly and operate well."

A number of countries are following a strategy of staged or incremental decision-making in this area. By proceeding with the development of waste management technologies in a staged manner, assessing safety can be separated from implementation activities and technology can be developed without invoking public concern associated with siting of storage or disposal facilities. This process of incremental decision-making is being followed as a means of building public confidence and, I would also say, technical confidence, in the face of uncertainties associated with perceptions of risk and risk measurement, with lack of confidence in large institutions, and with the performance of radioactive waste management facilities in the long term, over thousands of years.

We certainly face a considerable challenge in gaining public confidence that we can safely dispose of our wastes. But, as we have heard in the papers presented here, there is a clear way forward which can lead to success, through a dedication to safety, interaction with the public, and staged decision-making.

Reactor Safety

During the past few years, the maintenance and enhancement of the safety of *operating* power reactors has become a **"centre-stage"** issue, replacing the earlier **"star-billing"** given to the safety features of new plant *designs*. This is, of course, a direct consequence of the decline in committing new plants and the recognition that existing plants may well be called upon to operate for many years to come, because of economic and political problems associated with new construction in many countries.

Two papers presented in the Safety Session dealt directly with this situation, the first discussing the general question of the safety of aging reactors, and the second the more specific topic of the safety of operating reactors in the former Warsaw Pact countries.

In terms of the general question of aging, Dr. Herbert

Keats concludes that two basic thrusts are appropriate. First, the safety of older plants should be periodically reviewed and upgraded in those areas where modern safety analysis techniques demonstrate inadequacies which can be rectified in a practical, cost-effective manner. Second, close attention must continually be paid to long-term degradation mechanisms such as chemical change, wear, and neutron irradiation. The author emphasized the need to evaluate operating plants, using current techniques, against current acceptance criteria for new plants. The need to remedy identified deficiencies relative to these criteria would then be judged on a cost-effectiveness basis.

In the case of reactors in the former Warsaw Pact countries, Dr. Claus Berke concludes that, in most cases, shutting down these reactors because of safety concerns will prove impractical – the risks involved in their continued operation being offset by other risks which would arise from the severe energy shortages resulting from their shutdown. Nevertheless, much can be done to improve the safety of these reactors. The costs, however, will be high – ranging to several billions of dollars per year. The problem then becomes one of financing such investments. The author concludes that Western countries must find a solution to this problem if further Chernobyl-like accidents are to be avoided. Such further accidents might well lead to the premature and disruptive demise of the nuclear option in all countries.

The second paper, by Dr. Bernard Cohen, dealt with the relative risk to the public from nuclear power plants as compared to other primary energy sources and concludes that the risk from nuclear plants is very small. From this conclusion, one might logically argue that few, if any, safety upgrades to operating plants are justified – even in the case of plants in the former Warsaw Pact countries. Unfortunately, we in the nuclear industry have not succeeded in convincing the public that nuclear power risk is trivial and, hence, it seems likely that in most countries, the much more costly approach suggested in the paper on aging will prove unavoidable.

"It is up to scientists to take the lead in communicating with the public."

We heard a description of evolutionary design improvements to next-generation power reactor safety being developed by one vendor organization. This project is a cooperative effort between two national industries both of which have been major suppliers of nuclear plants in the past. This is indicative of a current world trend to cope with the cost of developing and constructing new nuclear power stations.

Several interesting trends are apparent in the area of reactor safety. Most designers are now turning to the development of passive safety systems to assure the correct response to upsets in their plants in the unlikely event of an accident. Several papers described concepts for passive cooling of the containment building as a means of ensuring containment integrity during a severe accident. Another development to mitigate severe accident consequences is the preferred use of "**core catchers**" to contain, spread and cool any molten core material within the reactor vessel. Consistent with the concerns of aging mentioned earlier, reactor owners are updating their safety reports and carrying out probabilistic safety assessments of their individual plants with the encouragement of their regulators.

Public Acceptance

Public perception is the pervasive and persistent theme that is interwoven through the nuclear fabric. Public opinion research clearly shows a dichotomy between the need for a secure supply of electricity and the perceived disadvantages of achieving it by using nuclear power.

In most countries nuclear is not a top-of-the-mind issue. There is little spontaneous concern or anguish about it, but when prompted, people express their worries and fears. They also express their lack of knowledge and their desire for information. Surveys of opinion leaders show that greater awareness of energy and nuclear matters improves their perception of nuclear power.

The data on public attitudes that were presented indicates that people regard the scientific community as the most trusted group for making decisions about science and technology, including nuclear energy. Politicians are the least trusted. For any of us who might feel that the media are responsible for our tribulations, it is a small measure of consolation that people don't trust the media either.

The lesson is clear, Dr. John Gittus concluded: it is up to scientists to take the lead in communicating with the public on difficult issues such as nuclear power. Other speakers qualified this assertion with an appeal for communicating in terms that the public are familiar with and can readily understand.

Mr. Archie Robertson reminded us that nuclear energy has been the subject of more than 30 national and international enquiries, none of which rejects nuclear energy, when needed and under stipulated conditions. Despite this endorsement, public acceptance has not been achieved.

Dr. Peter Feuz told us how the European nuclear scene is beset not so much by competing energy sources or unpredictable licensing procedures, but by public opinion and politics. "It is difficult to say whether public opinion is bad because of lack of political leadership, or whether this leadership is lacking because politicians do not want to go against public opinion," he said. He attributed the success of the French nuclear program to a combination of leadership and excellent public information initiatives.

Technology Developments

Let me now identify some of the technology developments which will be necessary to ensure that nuclear energy will be accepted as a vital component of the energy supply mix in the future.

Dr. Allan Bromley raised a number of interesting points. He noted that society has benefited from a number of revolutions in science and technology, beginning with the **industrial revolution.** More recently, we have experienced the development of nuclear energy, with the promise of abundant energy, the **green revolution** in agriculture, which seems to have grown into a concern and awareness for environmentally sustainable development, and the **information**

revolution, which is still gaining momentum.

If we are to keep the promise of nuclear energy alive and relevant for the next century, we must understand and address the issues raised by these succeeding "**revolutions.**" We must, in fact, embrace them. We can readily see from history what happened to those technologies which did not adapt and become part of the industrial revolution. Technological developments which assist and accelerate the evolution of nuclear energy to meet the needs and issues raised by the green revolution, and the information technology revolution, are therefore important to position it for a meaningful role in energy production for the next century.

It would be naive to think that we have been able to identify in this one meeting all of the technological developments that will be required. However, there are some clear directions indicated, and a number of developments are moving that way. Here are a few examples.

Continued developments in the area of waste management and resource utilization will be required to ensure that nuclear energy truly becomes part of the Green Revolution. The nuclear industry has been pro-active in dealing with its waste byproducts, but the public still perceives that there is not yet a "**demonstrated**" solution to the "**waste problem.**" To address this issue we need to push this technology to the demonstration phase. There have also been suggestions of how to make more effective use of our resources, and minimize the volume of waste through the application of advanced fuels and fuel cycles. Means of using off-peak nuclear generating capacity to produce hydrogen have been described. The latter would have the additional benefit of supplying an alternative to fossil fuels that is better for the environment.

Recognizing that the technology must evolve, there have been many improvements to reactors, and many more are being developed. Considering that it has been less than fifty years since the first nuclear generated electricity, the degree of evolution in this technology has been quite impressive. Nuclear generating stations being built today are sufficiently safe that the risk to the surrounding population is effectively zero. However, development of "**passive**" safety technology will place less reliance on engineered safety systems, and make the safety of nuclear stations more readily apparent and verifiable to the public. An important side benefit should be a reduction in cost. Fundamental research in materials and, physical sciences is also being applied to improve other reactor systems such as steam generators, and, specific to CANDUs, fuel channels, in order to ensure that plant performance is enhanced through extended lifetime of components.

"Advocates for nuclear power cannot afford to relax."

The nuclear industry must also continue to make advances in areas related to the Information Revolution. Improved information systems are already being used to reduce design and fabrication costs, which in turn reduces capital investment. Intelligent systems, neural networks, and other such developments are being applied to the man/machine interface in future plants to aid in making operating decisions. This is an important application of information technology and a good example of the need for and benefits from adapting new technology to existing products in order to make them faster, better, and less expensive.

Another of Dr. Bromley's messages is that our education system must be improved. Not only are bright well-trained scientists and technologists needed to help develop our industry, but an informed public is required to ensure that the right decisions are made in an increasingly complex and technologically sophisticated world.

Future Energy Strategies

As we determine our strategic posture for meeting future energy needs we must espouse change – attitudinal change, systemic change, new planning technologies. We must set and meet realistic goals for energy supply and demand. We must use available resources prudently and productively. We must seek efficiency and conservation, consistent with economic and environmental objectives. We must place energy issues in a global social and institutional context.

Mr. James Hann has reminded us how the promised New World Order has failed to materialize and how tomorrow's world might be one where political instabilities could pose major energy risks. "Advocates of nuclear power cannot afford, for one second, to relax," he told us. And he went on to exhort us to stand up for what we know to be right, and to put forward our powerful case with conviction and without defensiveness.

Conclusion

In summarizing the messages we have heard throughout the Congress, I shall try to outline how the world energy scene might unfold in the coming decades. What one sees is this:

- there will be a very large increase in the world demand for energy, mainly in developing countries
- fossil fuels will supply most of that increased demand, particularly if fossil-fuel prices remain stable
- nuclear energy will probably maintain its current share of the world energy market *if* nuclear plants can be built quickly and operate reliably, and *if* capital can be obtained at reasonable cost
- nuclear's share of the energy mix will increase significantly if fossil-fuel prices increase, or if there is increased concern about greenhouse gases
- new technological developments will lead to improvements in the safety and reliability of existing and future nuclear plants, with particular emphasis on improving the man-machine interface
- the public will be more involved in the development of acceptable processes for the management of nuclear waste, which will probably proceed in a staged manner
- the public will be consulted much more in the future on all nuclear issues, with more emphasis on listening to what the public has to say

Nuclear power still faces many challenges. But, from what I've heard in the past three days at this Congress, I'm more convinced than ever that it has a major role to play and that it will help us achieve our vision of a better future.

INC '93

Selected Summaries

Forming a significant part of the INC '93 International Nuclear Congress, held in Toronto, October 3 to 6, were the "Technical Sessions – Contributed Papers" which were organized by the Canadian Nuclear Society. In form these technical sessions closely modelled the annual conferences of the CNS which have been held in conjunction with those of the Canadian Nuclear Association.

At INC '93 there were 110 contributed technical papers presented over the three days of the conference; during the latter part of Monday morning and on Tuesday and Wednesday mornings. On Monday four sessions were run concurrently, while on the other days there were six sessions running in parallel.

Ben Rouben, of AECL CANDU (and CNS Treasurer) was chairman of the contributed technical program committee.

To give those unable to attend INC '93 some feeling for the diversity and nature of the papers presented in these "technical-contributed" sessions (which were not included in the review by Bruce Howe presented elsewhere in this issue) nine summaries are reprinted below. The selection of these nine is quite arbitrary – editor's choice – and does not denote any evaluation.

Copies of individual papers can usually be obtained from the authors. Proceedings, with full papers, are available from the CNS office. Ask for "INC '93, Contributed Papers Proceedings," Vols. 2 and 3. (Vol. 1 provides summaries of all of the "technical" papers, including the 18 "invited" ones, which were the focus of the Howe review.).

Liquid Relief Valve Failure Simulation in the Embalse Nuclear Power Station

Sara Gersberg, J.R. Lorenzetti, D. Parkansky and J. Batistic, Comision Nacional de Energia Atomica, Argentina.

Simulations of failure (open) of a liquid relief valve in the Embalse Nuclear Power Station heat transport system have been performed using the Firebird III computer code.

As only one loop was simulated (1 circuit model) we have made some assumptions to take into account the influence of the pressurizer and the unbroken loop.

- We have assumed that the two loops depressurize at the same rate.
- Since the unbroken loop compensates the loss of inventory in the broken loop, the discharge rate flow through the liquid relief valve was reduced to half of its calculated value. However, this assumption was not considered when the degasser condenser mass and energy balance was performed.

Results show that, without any operator action, and if the degasser "bottles up" (closure of a valve downstream of level control valves), the heat transport and the degasser pressure increase, reaching the relief degasser condenser valve opening. To avoid this loss of inventory, three operating procedures have been analyzed:

1) An initial reduction of power (0.5%/s).
2) The same power reduction following the pressurizer level recovery.
3) A trip when the pressurizer level falls below 7.5 m.

Results of the simulations indicate that the most convenient action is to reduce power when the pressurizer level stops decreasing.

Planning the Retubing of a CANDU 6 Reactor

N.G. Craik, Canatom Inc. and R. Baker, NB Power

The reactor fuel channel pressure tubes at the New Brunswick Power Corporation CANDU 6 Nuclear Generating Station at Point Lepreau, are known to have a number of design related mechanisms which will limit their performance life.

Most of these mechanisms are of concern only near the end of the normal 30 year life of the pressure tubes. However, one mechanism, caused by movement of spacers away from their correct design position, is pressure tube to calandria tube contact which may result in cracking of the pressure tube material. It is estimated that this could be a significant operating problem as early as 1998.

In 1993, utilizing the latest techniques in pressure tube inspection and maintenance technology, both Ontario Hydro and NB Power demonstrated for the first time that pressure tube to calandria tube contact could be eliminated without pressure tube replacement. This process, known as Spacer Location and Relocation (SLAR) offers an alternative to retubing and is being considered by NB Power for implementation in 1995.

Consequently, NB Power has been studying Large Scale Fuel Channel Replacement (LSFCR) either for implementation in 1998 or 1999 as a fallback position to SLAR or in 2008 when the pressure tubes will require replacement for other reasons. Either strategy would have the objective of achieving a 40 to 50 year plant life.

LSFCR has been undertaken at the four Ontario Hydro Pickering A Reactors. Plans for retubing the four Ontario Hydro Bruce 'A' units are well advanced. However, this is the first time that the methods of undertaking an LSFCR on a CANDU 6 have been studied in any detail. The initial focus of the Lepreau LSFCR planning is to see how the equipment and facilities similar to that used in the Pickering and Bruce LSFCR operations, can be applied to Lepreau.

NB Power prepared a 3D CAD's model of areas that will be involved in LSFCR and in the movement of large/long components in and out of both east and west fuelling machine vaults, from the main airlock, through the reactor building, including existing cranes. NB Power's studies on a method of LSFCR of the Lepreau 1 CANDU 6 show that the reactor building and facilities are significantly different to the Pickering and Bruce layouts and present some major problems. Potential solutions to these layout problems are presented.

Passive Emergency Heat Rejection Concepts for CANDU Reactors

N.J. Spinks, AECL Research

A study is in progress at AECL to assess the safety and capital cost implications of a more extensive use of passive design features in CANDU reactors. The study is focussed on emergency heat rejection and applies passive design principles to enhance the independence of core cooling via the moderator as distinct from core cooling via the emergency coolant injection system. Moderator heat rejection is effected by heat transfer from a heavy water natural circulation loop to a light water natural circulation loop which includes a water jacket formed in part by the cylindrical wall of a steel containment vessel. The water jacket acts as an interim sink for heat from both the moderator and containment and ultimately transfers its heat to the outside air. As with current CANDU designs, depressurisation is effected via the steam generators which are then supplied with emergency water by gravity from an overhead tank.

The concepts have been applied to a 2 loop CANDU 6 plant and a preliminary assessment has been completed, using simplified (pseudo-steady-state) methods, of an in-core LOCA, the limiting accident for moderator heat rejection. It is found that some pressurization of the moderator is needed to maintain subcooling at the fuel channel elevation. By examining the dominant core-melt sequences for a conventional CANDU 6 design, core melt frequency appears to be improved by at least an order of magnitude. Capital cost seems to be competitive with conventional plant.

Further calculations are in progress to reassess moderator heat rejection using more sophisticated techniques. Core melt frequency will be assessed from first principles by identifying the dominant core-melt sequences for the passive design.

Design enhancements are described: improvements in the fuel channel design eliminate the need for subcooling of the moderator and in turn eliminate the need for moderator pumps even during normal operation.

Nuclear Sources of Hydrogen in CANDU Fuel Channels

M. Aslam Lone, AECL Research

In this paper we examine the nuclear processes that generate hydrogen (the word hydrogen herein, refers to any isotope of the element), and give quantitative estimates of their contributions to the ingress of hydrogen in the fuel channels of CANDU reactors. These channels are exposed to high fluences of neutrons and gamma rays of energies up to tens of MeV and the nuclear processes that can generate noticeable amounts of hydrogen ions are:

- (n,p), (n,d), (n,t), (γ,p) and (γ,d) reactions in Zr, Nb and impurities in the tube material,
- elastic scattering of neutrons from H and D atoms in the cooling water, and
- photo nuclear reaction with D in the cooling water.

A CANDU 600 fuel channel was considered as a reference. The production of hydrogen isotopes from nuclear reactions in the tube materials, including possible trace chemical impurities of $Z < 50$, were examined. The cross sections for nuclei with $Z > 50$ are too low to generate noticeable amounts of hydrogen. The ingress of hydrogen generated by neutron elastic scattering and photo nuclear reactions were evaluated. The collisions of fast neutrons with hydrogen and deuterium atoms in the water molecules produce knock-on ions that can implant in the fuel channels. Similarly, the gamma-ray induced disintegration of deuterium will produce higher energy protons that can implant in the fuel channel.

The objective of this study was to examine the upper limits of the potential contributions from the nuclear processes. Thus where information on nuclear data and concentrations of chemical impurities was unavailable, upper bounds were adopted. The total ingress of hydrogen in the fuel channels was estimated assuming that the nuclear reaction products are trapped permanently in the fuel-channel material.

In a CANDU 600 reactor, the lattice array pitch is 28 cm and there is about 15 cm of heavy-water moderator between the adjacent fuel channels. With this configuration, the high-energy neutron flux in the pressure tube is predominantly due to the fission neutrons coming from the enclosed fuel channel. The neutron and gamma ray fluxes at the fuel channel location were obtained from reactor physics calculations with the codes WIMS and ANISN.

Cross sections for the nuclear reactions needed for this study were generally available from the compilations generated by the international nuclear data centres. The ingress of hydrogen in the pressure tube was calculated from the reaction yield of 1 g of the tube material placed in the neutron and gamma fluxes.

The total ingress from the nuclear sources over 20 years was calculated to be less than 4 ppm by wt. The study points to impurities like nitrogen that could generate high levels of hydrogen from the $^{14}N(n,p)^{14}C$ reaction.

Recovered Uranium in CANDU: A Strategic Opportunity

P.G. Boczar, J.D. Sullivan, H. Hamilton, AECL Research;
Y.O. Lee, C.J. Jeong, H.C. Suk, Korea Atomic Energy Research Institute; C. Mugnier, COGEMA

Recovered uranium (RU), a by-product from conventional reprocessing with a nominal U-235 concentration of 0.9%, is an attractive fuel for existing and future CANDU reactors. Its use without re-enrichment in CANDU would yield several benefits. Uranium utilization (the amount of energy derived from the mined uranium used in the original PWR fuel) is improved by about 40%. Because of the neutron efficiency of CANDU and the neutronic characteristics of RU, double the energy can be extracted from the RU by burning it in CANDU, compared to re-enriching it as a fuel for PWR. Fuel burnup in CANDU would be about twice that of natural uranium, resulting in a smaller volume of spent fuel requiring disposal, and a commensurate reduction in back-end disposal costs. By flattening the channel power distribution across the reactor core so that all channels produce nearly the same power, RU offers a power uprating capability in new reactor designs, or in existing reactors where there is sufficient heat removal capacity. Fuelling costs would be significantly lower than natural or slightly enriched uranium (SEU) in CANDU.

The suitability of RU as a reactor fuel for CANDU was assessed in a joint program between AECL and COGEMA.

RU powder, and pellets pressed from that powder, met CANDU fuel specifications. One issue that had been identified in an earlier assessment was whether trace amounts of Cs-137 in the RU powder would be released during sintering, and if so, whether this would condense in the cold part of a sintering furnace in a commercial fuel fabrication plant leading to a build-up in fields over time. This was assessed by sintering 4000 RU pellets in a furnace that had been designed with a cold-trap in which volatile Cs released during sintering would condense. This assessment showed that volatile Cs would not pose a radiological problem in a commercial fuel fabrication plant.

Fuel management studies were performed for a CANDU 6 reactor using the CANFLEX bundle with 0.9% SEU, representative of RU. These studies included time-average calculations, and a 120-day time-dependent refuelling simulation. A simple four-bundle shift, bi-directional fuelling scheme resulted in good axial power profiles, and a refuelling rate in bundles per day that was half that of natural uranium, and, in terms of channels per day, comparable to that of natural uranium. Peak time-average channel and bundle powers were 6406 kW and 757 kW, respectively. During the refuelling simulation, the maximum channel power varied between 6500 kW and 6700 kW, and peak bundle power was between 800 kW and 830 kW, well below licensing limits, and comparable to natural uranium. Peak element ratings during the refuelling simulation were below 45 kW/m, which would facilitate good fuel performance at extended burnup. Significant power boosting during refuelling occurred only for relatively fresh fuel, which is tolerant to power boosts. The reactivity worths of control devices is acceptable for safety and control functions.

Fuel cycle economics were assessed for RU in CANDU and re-enriched RU in a PWR. The potential savings in CANDU fuel cycle costs with RU are striking, and significantly greater than the potential cost savings for re-enriched RU in a PWR. With RU at no cost, front-end fuelling costs are reduced relative to natural uranium fuelling by 45% with natural uranium at $25/kg, and by 67% with natural uranium at $80/kg. With RU at natural uranium costs, the fuelling cost savings with RU are 28% for natural uranium at $25/kg, and 34% for natural uranium at $80/kg. Hence, there is a compelling economic incentive for using RU in CANDU.

In summary, excellent neutron economy creates a niche in which CANDU is uniquely suited for burning RU without re-enrichment.

Operating Under Fire The French Way

F. Bediou and J.P. Chatry, E.D.F.-C.I.G., France

Fire protection in nuclear plants usually has three aspects: prevention, detection and fire fighting. Prevention mainly consists in avoiding that a single fire may render two redundant safety systems unavailable. Detection aims at rapidly locating a starting fire, giving the alarm, and sometimes initiating automatic actions.

Fire fighting is organised to extinguish any fire fast. In French plants, an operator is sent to confirm the fire and to extinguish it. In case of difficulty, he isolates the area, informs the control room who will call for outside support.

In addition to this organization which aims at both the fire and its direct consequences, Electricité de France has developed an approach that allows the safe operation of the unit. This approach makes the assumption that the fire remains confined in a fire compartment, but all the electric equipment within this compartment is liable to be damaged and is subject to spurious faults. In order to mitigate these faults, all actuators are de-energised, and these de-energisations are programmed in such a way that untimely actions are avoided. The analysis determines which operational functions are unavailable due to this de-energisation. The list of unavailabilities allows the selection of the correct operating procedure. Each procedure is structured according to the function to be ensured (core cooling, water level or anti-reactivity margin) and for each function, according to the systems necessary or their possible substitutes.

This approach implies that one can prove that whatever compartment is on fire, at least one substitute system for each safety function is available. The electrical distribution gives great importance to the A-train as only the redundant protection and safeguard systems are supplied by the B-train. For the control room operator to have sufficient means to bring the plant to a safe shut-down state in case of a total loss of the A-train, it is preferable to ensure the availability of some minimal operating systems in addition to the B-train ones. In practice, this imposes the protection of a few control and power cables from non-redundant systems necessary for operator information or for long term operation.

The Role of Engineered Barriers in the Disposal of Nuclear Fuel Waste – The Canadian Perspective

K. Nuttall and L.H. Johnson, AECL Research

The concept developed in Canada for disposing of nuclear fuel waste is disposal at a depth of 500-1000 m in plutonic rock of the Canadian Shield. The waste would be isolated from the biosphere by a multi-barrier system consisting of engineered components supplementing the natural containment potential of the host-rock. The key engineered barriers are the waste form itself (used CANDU fuel), the container that holds the waste form, and sealing materials used to envelop the container and to backfill and seal the vault excavations.

During the past fourteen years, AECL has carried out a comprehensive research program on the design, materials selection, and performance assessment of engineered barriers. The research has recognized the generic nature of the concept development phase of the program whilst taking account of the key parameters characteristic of the plutonic rock disposal environment. The research approach has included studies of underlying processes, large-scale component testing and demonstration, conceptual engineering, model development and the study of natural analogs. On the basis of the research we have:

- developed a number of container designs that meet the primary structural requirements that will exist in a disposal vault.
- demonstrated that both copper and titanium can provide long-term containment of the waste; depending on material choice and container wall thickness, lifetimes between 10^3 and 10^6 years are considered achievable.

- demonstrated that intact used fuel bundles are a highly durable waste form from which most of the radionuclides will be released at a slow rate controlled by the low solubility of the UO_2 fuel matrix.
- demonstrated that cement- and clay-based materials can provide effective sealing of excavated openings and a physico-chemical environment that ensures that radionuclide transport between the container and the host rock occurs primarily by diffusion rather than by groundwater flow.

The results have demonstrated that there is considerable flexibility in the selection of materials and designs for engineered barriers for a disposal system in plutonic rock that could meet potential constraints that might be imposed by conditions at an actual disposal site.

Nuclear Hydrogen – Cogeneration and the Transitional Pathway to Sustainable Development

Gary M. Gurbin, Integrated Energy Development Corp.; K.H. Talbot, Ontario Hydro

The atmospheric consequences of carbon and the evolution of world energy sources have resulted in a movement away from high carbon fuels, and a growing appreciation that the next generation of industrial development must be on a sustainable basis.

Although some legislation, such as the U.S. Clean Air Act, 1990, have resulted in a significant shift toward higher hydrogen and oxygen content transportation fuels, the net consequence can be negative to the global environment. The objective of sustainable development is clear, but the implementation remains elusive and lacking focus.

The Bruce Energy Centre has been evolving for nearly two decades, driven by a mission to commercially demonstrate the importance of integrating energy, the environment, and the economy in industrial development. The nearby Bruce Nuclear Generating Station 'A' has provided process steam for operation of a fermentation alcohol plant, alfalfa processing plant and fullscale greenhouses.

The development of the next phase of the Energy Centre, in cooperation with Ontario Hydro, will see the introduction of a series of integrated energy processes whose end products will have environmental value added.

Cogenerated nuclear steam and electricity were selected on the basis of economics, sustainability, and "zero" carbon emissions. The introduction of hydrogen to combine with CO_2, from alcohol fermentation provides synthetic methanol as a feedstock to refine into ether for the rapidly expanding gasoline fuel additive market. Large volumes of O_2 will enhance combustion processes and improve closed-looping of the systems.

Ammonia synthesis, municipal solid waste separation, cellulose conditioning, residual oil upgrading, aquafarming and additional greenhouse projects are in the planning stage.

In the implementation of the commercial development the first stage will require simultaneous electrolysis, methanol synthesis and additional fermentation capacity. Electricity and steam pricing will be key to viability and an 80 MW "back-up" fossil fuelled, back pressure turbine cogeneration facility could be introduced in a compatible manner.

Successful demonstration of transitional and integrating elements necessary to achieve sustainable development can serve as a model for electric utilities throughout the world.

AECL's Impela™ Electron Accelerators fo Industrial Uses

Andrew J. Stirling, AECL Accelerators

In November 1992, AECL Accelerators completed the design, construction and commissioning of the world's most powerful 10 MeV electron accelerator in a commercial processing plant. The plant is owned and operated by E-Beam Services Inc. of New Jersey. The accelerator is AECL's Impela™ electron linear accelerator. It is characterized by its energy of 10 MeV and power of 50 kW. This high power level opens new horizons for the use of electron beams for modifying materials. The accelerator facility at E-Beam Services plant in Cranbury is a contract service centre. The products treated include medical devices that are sterilized, plastic pellets that are crosslinked, and formed plastic parts that are strengthened through crosslinking.

In executing the project in New Jersey, E-Beam Services designed and constructed the building, constructed the radiation shield, provided the personnel safety system and had the electrical and cooling services installed. AECL designed, built, installed and commissioned the accelerator. Both parties were under extreme pressure to meet the schedule. AECL's future clients and competitors were scrutinizing the progress minutely to assess the new technology. For E-Beam Services the pressure came from clients requiring firm dates before they could commit to processing contracts.

AECL's Impela™ is constructed to some 2300 controlled drawings, calling on standard and custom components from both foreign and local suppliers. The key item is the 3m high-purity copper accelerating structure. This consists of 58 close-tolerance cavities brazed face to face. Machining, tuning, brazing and vacuum testing were performed at AECL's former Medical Products plant.

The construction of the facility followed straight-forward building practices. E-Beam Services acted as its own general contractor, and purchased a prefabricated building. Accelerator installation was carried out by AECL staff and contractors from the local area.

The Impela™ accelerator at E-Beam Services was installed and commissioned fast and efficiently for the first model of its type and located outside the supplier's home country. It was completed a few days ahead of schedule due to excellent experience during commissioning. The elements which led to this success included:

- Excellent and frequent communication between project managers of supplier and client,
- Competent project managers,
- Access to highly qualified contractors in the New Jersey area,
- Accelerator design complete and fully documented before construction, and
- Having a prototype operating prior to construction so that lessons were learned in the laboratory rather than in the client's plant.

The Impela™ is now operating at full power routinely in the E-Beam plant. Its installation will, in all likelihood, mark a new chapter in industrial radiation processing.

Bruce 'A' Progress

***Ed. Note:** The operators of Ontario Hydro's Bruce 'A' NGS continue to be faced with challenging problems.*

Following are brief updates, as of the end of September, 1993, on two of these, as provided by Rick Day of the Bruce 'A' staff.

The first deals with a phenomenon identified in an extension of the analyses of loss-of-coolant accidents which showed that if a channel had less than a full complement of fuel bundles (say during refuelling) the shifting of the fuel due to reversal of flow caused by a LOCA could result in a positive reactivity transient. Subsequently, it was shown that even with a full channel this phenomenon could occur (at a much smaller magnitude) because of the lengthening of the fuel channels during operation.

The second concerns the continued observations of fret marks on the inner walls of the pressure tubes, presumably due to vibration of the fuel bundles.

Power Pulse

All units at Bruce 'A' NGS are presently limited to 60% full power due to the potential occurrence of a power pulse caused by a postulated guillotine failure of the primary heat transport system reactor inlet header. The probability of such an event is extremely low. The power pulse occurs when the newest fuel bundles in the most downstream position of the fuel channel are caused to shift backward into the core, introducing positive reactivity. The gap into which the fuel shifts varies in size depending on the amount of creep elongation that channel has experienced. Safe reactor shutdown is not jeopardized but the power pulse leads to undesirable overheating of the fuel bundles.

The solution being pursued involves modifying the existing shield plugs residing at the inlet end of the fuel channels by installing a flow straightening spacer thus reducing the gap and hence the amount of backward shift. Implementation of this will commence in October, 1993.

In addition, one of two other concepts presently being pursued will be implemented to further reduce the power pulse problem. One is the loading of fuel bundles which are 0.5 inches longer than the normal 19.5 inch long fuel bundle. The length of the 13 bundle fuel string including several long bundles will further reduce the gap. The second is to fuel the channel from the upstream or inlet end (fueling with the flow). This results in the oldest least reactive fuel bundles shifting back into the core in the postulated accident and introducing negative reactivity, which is inherently safe.

The Atomic Energy Control Board is presently reviewing the proposed programs. Full power production capability is expected during 1994.

Fuel Channel Fretting

Fretting marks less than 0.3 mm deep in the inner wall of reactor fuel channel pressure tubes which are 4.2 mm thick are being caused by turbulent flow induced fretting from the fuel bundle bearing pads.

A fret mark having a sharp root radius is susceptible to crack formation due to a combination of high residual stress in the crack region and high deuterium concentration in the zirconium pressure tube wall. The worst location for fretting therefore is in the inlet rolled joint area of the pressure tube where there is potential for delayed hydride cracking, large residual stresses in the rolled joint between the pressure tube and the end fitting, and high turbulence. The in-service inspection program requires this area of the pressure tube be inspected in approximately 10 fuel channels of each reactor unit every 2 years or 10 thermal cycles.

Efforts to reduce these phenomena include: improved fuel bundle design to reduce fretting damage (e.g. rounded bearing pads); installing flow straightening shield plug spacers, and; implementing the long fuel bundle program or reducing the number of fuel bundles in a fuel channel from 13 to 12 after implementing fueling with the flow.

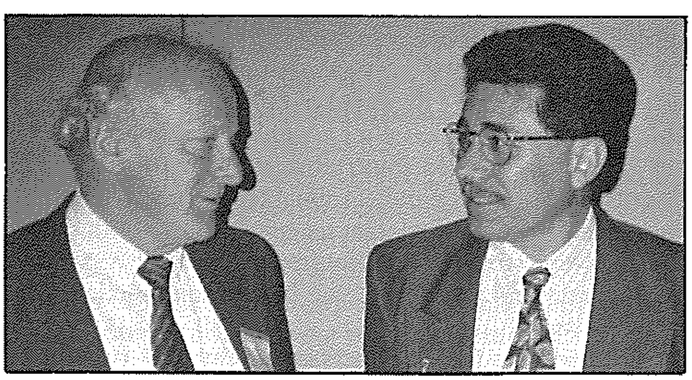
It is anticipated that the rounded bearing pads will increase the root radius of the fret mark and hence reduce the stress concentration factor.

Flow straightening shield plug spacers required for the power pulse issue will also serve to reduce turbulence at the inlet region of the fuel string, reduce bundle motion and hence fretting.

If fueling with flow with a 12 bundle fuel channel were implemented, fretting at the rolled joint would be eliminated and elsewhere would be spread out over a distance of several inches over the life of the pressure tube due to creep elongation. In addition, there is evidence to show that irradiated fuel bundles cause more severe fretting possibly due to distortion of the fuel elements and / or radiation hardening of the bearing pads. It is expected that the presence of new unirradiated fuel bundles at the inlet location would result in reduced fretting.

Installing long fuel bundles would also eliminate fretting in the rolled joint region but would spread out fretting elsewhere over a shorter distance of approximately two inches.

Both fueling with flow and long bundles are being considered for solutions to the power pulse problem outlined above as well as being of benefit to minimizing fretting.



Ed Price, CNS vice-president and Gary Kharshafdjian, chairman of the organizing committee, confer during the international Conference on Rolled and Expanded Joint Technology in Toronto, September 1993.

International Conference on Expanded and Rolled Joint Technology

About 70 specialists from Europe, Japan, and the USA, as well as Canada, convened in Toronto, September 13 and 14, 1993, to share their experience and research at the International Conference on Expanded and Rolled Joint Technology.

Primarily sponsored by the Canadian Nuclear Society, with co-sponsorship of the American Nuclear Society, the American Society of Mechanical Engineers and the CANDU Owners Group, this was the first full conference on this important technology. Although many of the Canadian papers reflected the vital role of expanded and rolled joints in CANDU reactors, there was considerable emphasis on the application of the technology in steam generators and heat exchangers. In fact the conference did attract limited support from the chemical industry but it was apparent to many that a large number of companies manufacturing heat exchangers, condensers and other equipment using tube deformation seals would have benefitted from attendance.

Professor Andre Bazerqui, Dean of Ecole Polytechnique, University of Montreal, opened the conference. Professor Bazerqui has worked in the field of tube to tubesheet joints and reviewed some of that experience for the conference. An active group continues the work at Ecole Polytechnique under Prof. Chaaban.

The conference was structured in five parts: design, analysis and modelling, experimental measurement: tool design, and deterioration (although all of the papers did not necessarily fit strictly into these categories).

Stanley Yokell, representing the ASME, set the stage for the conference by recounting the history of expanded joints from their first significant use in the mid 1800s to the present day. He was followed by Dr. Miro Podhorsky of Balke-Durr in Germany, one of the pioneers of the tube expansion technique, who reviewed the basic mechanisms of the sealing process. Speakers from Westinghouse, USA, Framatome of France, and Babcock and Wilcox Canada, reported on their experience and current practice on nuclear steam generators, where in each case, hydraulic expansion has become the preferred method of crevice closure for the tube to tubesheet joint. Prof. Updike of Lehigh University described a software program that quickly evaluated the properties of expanded joints for heat exchanger applications.

Several papers dealt with the difficult problem of modelling and analyzing these mechanical joints. Various approaches of applying finite element analysis were presented by speakers from the USA, Canadian universities, Ontario Hydro and AECL.

S. Venkatapathi, of AECL Chalk River Laboratories, presented three papers (prepared with co-authors A. Mehmi, H. Wong and N.C. Johnston) dealing with: (1) the pressure tube to end-fitting joint, (2) the calandria to tubesheet joint, and, (3) an overall one on all expanded joints in CANDU reactors. (The last is reprinted in this issue).

The session on experimental measurement produced some interesting papers. Mr. J. Kissel of ITT-Standard Inc. presented results showing the high temperature strength properties of different joint combinations. Dr. Kodoma of Mitsubishi discussed the measured residual stresses in different types of joints while Mike Flaman of Ontario Hydro Technologies described hole drilling residual stress measurement procedures in pressure tube joints.

Two presentations by John Sherer of Sherex Industries and Craig Virkus of Elliot Company respectively, dealt with the practice of joint fabrication, outlining the techniques and current tool and equipment developments.

An important feature of the conference was a panel session chaired by Prof. M. Dokainish of McMaster University who also leads a research group exploring tube to tubesheet joint behaviour. The discussion was lively, covering comments on the validity of finite element programs; the possible future direction of ASME in codifying recommended practice; the performance of tube to tubesheet joints at elevated temperatures; leak testing, the importance of surface condition and grooves on joint strength.

Papers in the final session, on deterioration, discussed residual stresses and the associated stress corrosion cracking, and the particular problem of hydrogen (or deuterium) ingress at pressure tube rolled joints in CANDU reactors. The papers by Dr. T. Kodoma of Mitsubishi Heavy Industries and Mr. A. McIllree of EPRI reviewed the effect of fabrication variables on residual stresses in expanded and rolled Inconnel 600 joints, and thus their susceptibility to stress corrosion cracking. Two papers presented by A. White and D. Cann of AECL Research described the techniques being developed to reduce hydrogen ingress into pressure tubes at rolled joints by chromium plating, or by removing the hydrogen with yttrium getters. Yttrium is one of the few elements able to draw hydrogen away from zirconium alloys.

In summary, the conference showed that the technology of deformation joints has matured significantly in the past 10-15 years. Hydraulic expansion is finding increased usage in applications where the speed of fabrication and relatively low residual stresses left after assembly, are important. On the other hand, rolled joint fabrication, particularly with the developments in parallel rolling techniques, will remain the principal mechanical joint technique where both sealing and pull-out strength are required. Hopefully ASME will codify analytical procedures and fabrication practice in the next few years.

The high standard of papers and the smooth running of the conference is testimony to the organizers, especially Gary Kharshafdjian and Ed Price, and the members of the CNA/CNS office who assisted them. The proceedings of the conference will be available from the CNS office later in the year.

Roll-Expanded Joints in CANDU Reactors*

S. Venkatapathi,[1] N.C. Johnston,[2] and A. Mehmi[2]

Foreword

Roll-expanded joints are used extensively in the reactor assembly of CANDU PHWRs and they have performed reliably in commercial power reactors for 25 years. They provide a cost-effective means of joining components of dissimilar materials and enhance the ease of replaceability of the respective sub-assemblies. The joints require no maintenance and they require minimal space.

Each application requires a distinct joint design due to the differences in the service conditions, dimensions and materials of construction of the components, performance requirements and installation considerations.

This paper describes the roll-expanded joints used in the following applications in CANDU reactor assembly: (a) the joint between the zirconium alloy pressure tube and the stainless steel end fitting in the fuel channel assembly, (b) the joint between the liner tube and the end fitting body, (c) the joint between the zirconium alloy calandria tube and the stainless steel calandria-side tube sheet in the calandria, (d) the joint between the fuel channel annulus bellows assembly/ fixed-end-stop collar and the lattice tube at the fuelling machine tube sheet, and (e) the joints between the zirconium alloy guide tube and the stainless steel outer hub in the flux detector assembly.

CANDU REACTOR

The calandria vessel in a CANDU reactor (Figure 1), is a horizontal, cylindrical shell with two end shield assemblies. Each end shield assembly consists of two tubesheets (calandria and fuelling machine tubesheets, respectively), and is spanned horizontally by 380 or 480 lattice tubes. The lattice tubes in each end shield are arranged on a 286 mm (11.25 in) square pitch to form a circular lattice array. The outboard end of the lattice tube is welded to the fuelling machine tubesheet bore and roll expanded to eliminate any crevice geometry that could result in crevice corrosion.

At each lattice site, a Zircaloy 2 calandria tube, about 6 m (235 in) long, is installed between the calandria tubesheets. A stainless steel insert is installed into the end of the calandria tube. The insert and calandria tube are roll-expanded into the calandria tubesheet, using a "sandwich" joint.

A fuel channel assembly (Figure 2) is installed in each calandria tube. Each fuel channel consists of a Zr-2.5% Nb pressure tube connected to AISI 403 stainless steel end fittings at each end by a roll-expanded joint. The pressure tube forms the in-core portion of the fuel channel.

The end fittings are the out-of-core extensions to the pressure tubes. They provide connections to various interfacing systems (primary heat transport feeder pipe, fuelling machine and annulus gas system bellows assembly). The outboard end of each end fitting is sealed by a channel closure, which is removed and replaced by remotely operated fuelling machines during on-power fuel-changing operations.

Inside each end fitting resides an AISI 410 liner tube. The liner tube acts as a channel for the movement of the fuel bundles between the fuelling machine and the coolant tube. It also supports and locates the shield plug. Adjacent to the inboard end of the liner tube are a number of holes spaced around the circumference. These holes provide the passage for the coolant between the end fitting and the pressure tube through the shield plug.

In CANDU 6 reactors, the liner tube is roll-expanded into the end fitting just outboard of the pressure tube-to-end fitting joint.

The channel annulus consists of (a) the annular gap between the pressure tube and the calandria tube and (b) the annular gap between the end fitting and the lattice tube. It is isolated from the atmosphere of the reactor vault. The channel annulus is sealed at both ends by bellows assemblies in all CANDU reactors, except BRUCE NGS A, Units 1, 2 and 3, where the channel annulus is closed by a bellows assembly at one end and by a fixed-end-stop collar at the other end. The bellows has a ferrule welded to one end and a flanged sleeve welded to the other end. The ferrule of the bellows (or end-stop collar) is connected to the fuelling machine-end of the lattice tube and the flanged sleeve is welded to the bellows attachment ring which is shrunk on to the end fitting. The roll-expanded joint is one of the methods used to join the bellows assembly to the lattice tube. The fixed end-stop collar is connected to the lattice tube using the roll-expansion process.

The channel annulus is connected to the rest of the annulus gas system by means of a 6 mm (0.25 in) diameter stainless steel (304L) tubing. One end of the tubing is roll-expanded into a hole in the bellows ferrule before being welded to the bellows ferrule.

Vertical and horizontal reactivity control devices are used to provide power-sensing, control and shut-off features. They are installed in the guide tubes, which penetrate the calandria, passing between the calandria tubes. The flux detector unit is one of the control devices and it measures the fission rate within the reactor. The guide tube assembly for the flux detectors is a zirconium alloy (Zircaloy 2) tube that is roll-expanded into a stainless steel (304L) tube at one end.

PRESSURE TUBE-TO-END FITTING JOINTS

Joint Description

The pressure tube in a CANDU fuel channel is a cold worked Zr-2.5%Nb seamless tube, 103 mm (4.07 in) inside diameter x 4.1 mm (0.165 in) thick x 6.3 m (248 in) long. It is roll-expanded into the end fittings at each end. The end fitting is

1 AECL Research, Chalk River Laboratories, Chalk River, Ontario

2 AECL CANDU, Mississauga, Ontario

* Presented at the International Conference on Expanded and Rolled Joint Technology

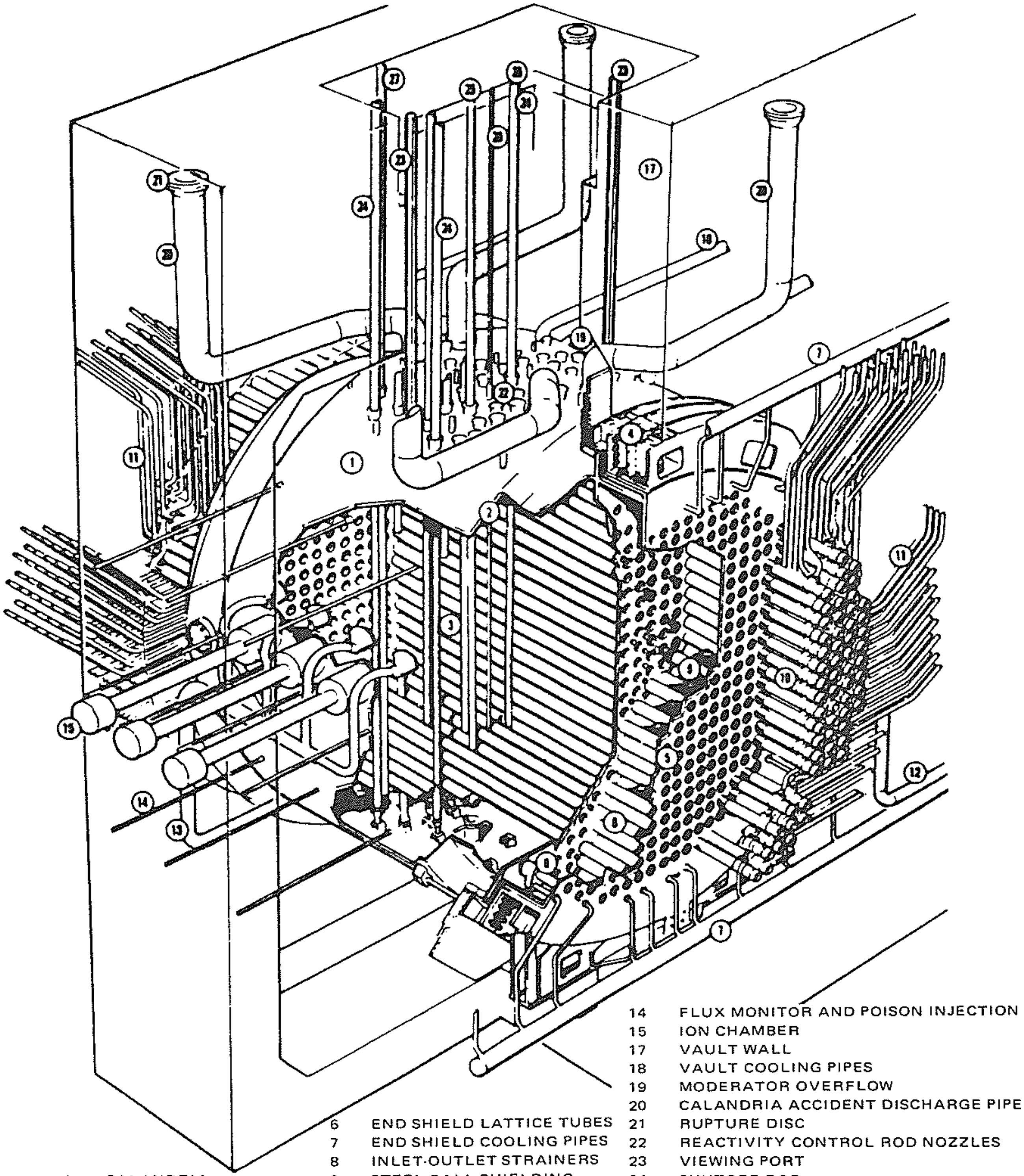


Figure 1: CANDU 6 Reactor Assembly

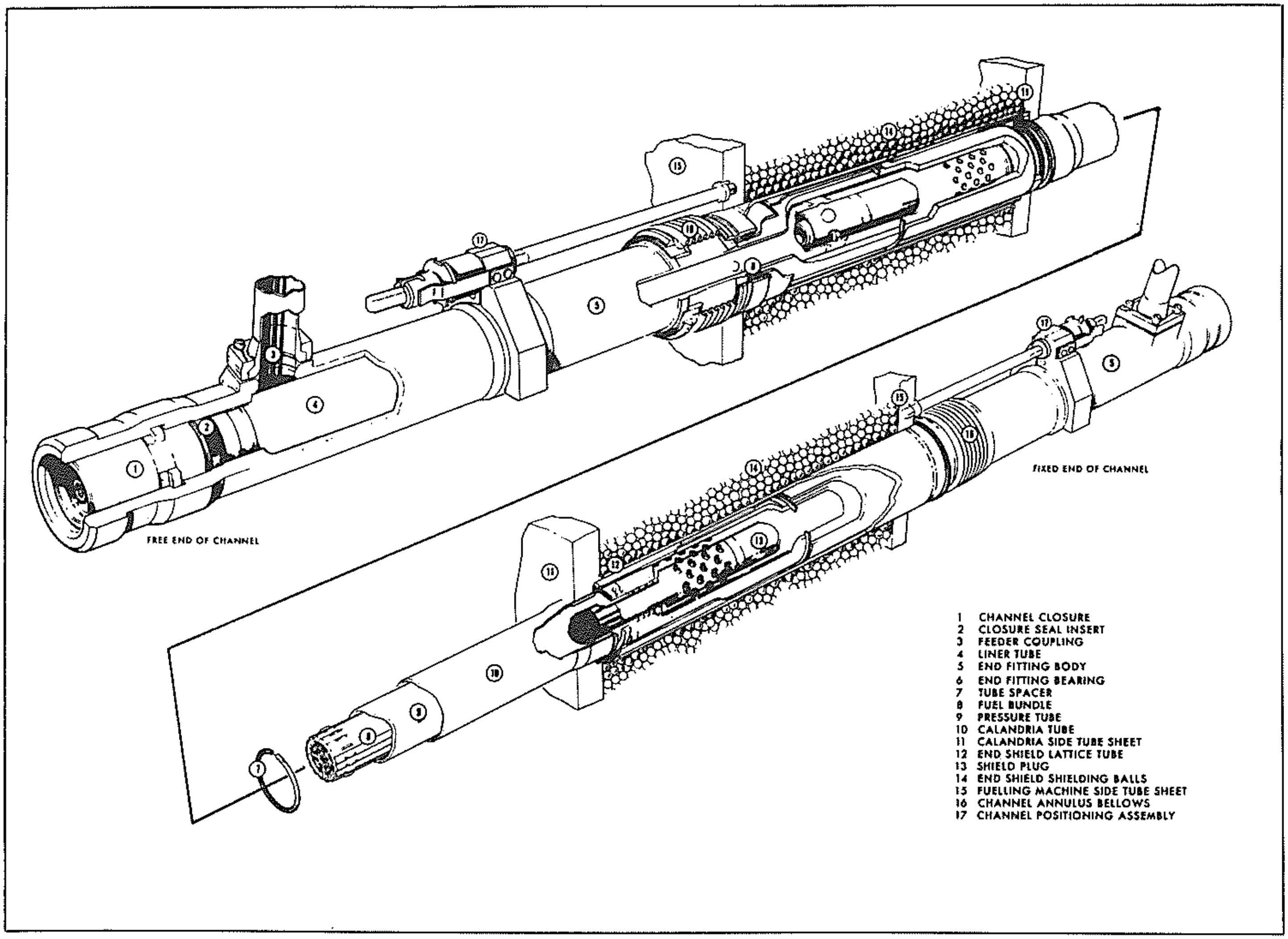


Figure 2: CANDU 6 Fuel Channel Assembly

fabricated using a modified 403 martensitic stainless steel forging. At the region of the connection to the pressure tube, the body of the end fitting has a tubular section, 165 mm (6.5 in) outside diameter x 25 mm (1 in) thick. Three circumferential grooves are machined at the inside surface of the end fitting.

The pressure tube is roll-expanded into the end fitting to achieve a reduction of 13.5% in the wall thickness of the pressure tube. During the roll-expansion, the pressure tube material is forced into the three grooves in the end fitting, to provide a strong and leak-tight joint (Figure 3).

Operating Conditions

During reactor operation, the roll-expanded joint is at a temperature of approximately 300° C and is subjected to an internal pressure of about 10 MPa. It is subjected to mechanical loads resulting from the internal pressure, axial loads from the interfacing components, bearing friction, bearing reaction and thermal loads. The rolled joint is in an environment of low neutron flux and low fields of particle and electromagnetic radiations. The inside surface of the pressure tube is exposed to primary heat transport D_2O. On the outside, the inboard end of the roll-expanded region is exposed to the annulus gas (CO_2).

Design Requirements

During the design life of the fuel channel, the roll-expanded joint must provide a strong, leak-tight and reliable connection between the pressure tube and the end fitting assembly. To address this objective, the roll-expanded joint is required to meet the design requirements of (a) pullout strength, (b) leak-tightness and (c) residual stresses in the pressure tube and the end fitting. The geometry of the inside surface of the pressure tube at the roll-expanded region must permit unrestricted passage for the fuel and provide the necessary support to the fuel.

Maximum acceptable tensile residual stress levels in the pressure tube are specified to mitigate the occurrence of *D*elayed *H*ydride *C*racking (DHC) in the zirconium alloy pressure tube. The residual stress levels in the end fitting at the roll-expanded region are considered to assess the fracture resistance of the end fitting.

Applicable Codes and Standards

The joint is designed in accordance with Canadian Standards Association Standard, CAN3-N285-2-M89, "Requirements for Class 1C, 2C and 3C Pressure-Retaining Components and Supports in CANDU Nuclear Power Plants". The codes and standards applicable to the pressure tube-to-end fitting roll-expanded joints are discussed in detail in Reference 1.

Stress Analysis

The operating stresses in the pressure tube and the end fitting at the roll-expanded region are determined using a finite element stress analysis. The design rules of the ASME Boiler and Pressure Vessel Code, Subsection NB 3200, are used in the stress analysis. The analysis is included in the stress report of the fuel channel assemblies.

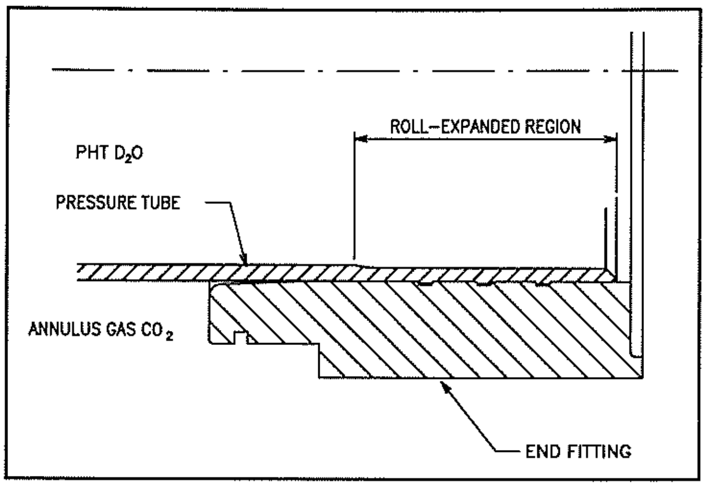


Figure 3: Pressure Tube-to-End Fitting Roll – Expanded Joint

Design Evolution by Testing

Performance of a roll-expanded joint is affected by the mechanical properties and the geometries of the interfacing components and the fabrication procedures. Analytical modelling of the roll-expansion process is further complicated by the anisotropic nature of the pressure tube material, the dynamic aspects of the roll-expansion process and the existence of a three-dimensional elastic-plastic state in the rolled joint assembly. Therefore, the design of the joint relies heavily on full-scale component tests during feasibility, development and qualification phases in the evolution of rolled joint design. More than 800 pressure tube-to-end fitting roll-expanded joints have been tested during the development programs. Therefore, the joint design is backed by extensive experimental data.

Factors Affecting Joint Performance

The performance of the pressure tube-to-end fitting roll-expanded joint is affected by: (a) the degree of roll-expansion, (b) the average diametral fit, (c) the material properties and the geometries of the pressure tube and the end fitting, (d) the geometry of the grooves, (e) the alignment between the pressure tube and the end fitting before and during roll-expansion, (f) the condition of the mating surfaces, (g) the length of the joint and (h) the roll-expansion procedures. The effects of the above variables on the performance of the joint are discussed in Reference 1.

During the full-scale component testing, the tests are planned (a) to address the effect of the above variables, both individually and in combination, on the performance of the joint, and (b) to ensure that, within the qualification envelope of the variables, acceptable joints are achieved consistently.

Degree of Roll-Expansion

The degree of roll-expansion is quantified by the reduction in wall thickness of the pressure tube during roll-expansion. The inside diameter of the pressure tube after roll-expansion is measured in every joint and is used to calculate the wall reduction. The wall reduction, which is calculated per above, is the "apparent" wall reduction, because the increase in the inside diameter of the pressure tube during roll-expansion includes, in addition to pressure tube wall reduction, the permanent diametral growth of approximately 0.05 mm (0.002 in) in the end fitting. The actual reduction in the wall thickness of the pressure tube is measured during the development test programs (Reference 1).

Production Roll-Expansion of the Joints

The fuel channels are installed in the calandria at the reactor site.

During the installation of the fuel channels, the cleanliness of the components, tools and work area is maintained stringently. Only water-soluble lubricants are used on the rollers. The inspection of the expander and rollers and the replacement of rollers are done on a routine basis at specified intervals. A refinery-type expander is used.

Prior to commencing production, all assembly, roll-expansion and inspection procedures, operators and tooling are qualified by producing a specified number of acceptable joints in a full-scale mock-up of the fuel channel.

Relevant dimensions of the pressure tube and the end fitting are inspected at site to ensure their conformance with the specifications. The pressure tube is trimmed to the required length.

During the fabrication of the CANDU pressure tube-to-end fitting joints, the following fabrication variables are stringently controlled: (a) the nominal apparent wall reduction, (b) the average diametral fit between the outside diameter of the pressure tube and the inside diameter of the end fitting, (c) the axial location of the inboard end of the roll-expanded region relative to the inboard end of the parallel bore in the end fitting, and (d) the alignment between the pressure tube and the end fitting before and during rolling.

After the roll-expansion, the following dimensional measurements are made: (a) the inside diameter of the pressure tube in the roll-expanded region, (b) the axial location of the inboard end of the roll-expanded region and (c) the dimensional measurements, to determine the effect of axial extrusions and rotation of the pressure tube on the geometry of the fuel channel. All rolled joints are subjected to a helium leak test.

Operating Experience

In early commercial power reactors, constructed before 1975, incorrect roll-expansion procedures produced excessive residual tensile stresses in the pressure tube just inboard of the roll-expanded region. At some of the rolled joints in the earlier reactors, the residual stresses were sufficiently high to initiate DHC in the pressure tube. Seventy three channels were replaced in the earlier reactors due to DHC occurrence. The revised roll-expansion procedures have eliminated the high stresses in the pressure tube in the reactors which were constructed since 1975.

There are more than 20 000 pressure tube-to-end fitting roll-expanded joints in the twenty four CANDU commercial power reactors in operation. Except for the joints in the seventy three channels mentioned above, the joints have not caused any reactor incapability.

The ease of replaceability of the fuel channel has been demonstrated by the successful large scale fuel channel replacements in the four reactors in Pickering NGS A, and by the routine single fuel channel replacements in various reactors for pressure tube surveillance examinations.

The rolled joints from the fuel channels, which were removed from the reactor after service, have been tested to determine their pullout strength and residual stresses. The post-service pullout tests have confirmed that the in-reactor service did not affect the strength of the rolled joint.

The residual stresses in the pressure tube decrease during reactor service, due to stress relaxation. The post-service measurements of the residual stresses have validated the theoretical model that was developed to calculate the extent of the stress relaxation during reactor service (Reference 1).

Recent research and development efforts in pressure tube-to-end fitting roll-expanded joints are addressing: (a) the improvements to the geometry of the inside surface of the pressure tube at the roll-expanded region, to improve the fuel passage, (b) design of the joints for the next generation of fuel channels with improved replaceability, (c) mitigation of life-limiting factors (e.g., deuterium ingress), and (d) the development of an analytical finite element model to simulate the roll-expansion process and predict the performance characteristics of the joint.

CALANDRIA TUBE-TO-TUBESHEET JOINTS

Joint Description

The calandria tube in a CANDU reactor is a large-diameter tube, 1.37 mm (0.054 in) thick and about 6 m (235 in) long, made from a Zircaloy 2 strip. The inside diameter of the body of the tube is 129 mm (5.077 in). The end sections, 148 mm (5.8 in) in length, are flared to an inside diameter of 140 mm (5.502 in).

Calandria tubesheets (304L), to which the calandria tubes are joined at both ends, are 40 mm (1.56 in) thick at the joint.

The geometry of the calandria tube (high (inside diameter/wall thickness) ratio) does not favour the use of conventional roll-expanded joints. The joint design must not cause unacceptable distortion to the tubesheet and it must not induce excessive tensile and torsional residual stresses in the calandria tube. The above conditions necessitated the development and qualification of a unique joint: namely, a "sandwich" type roll-expanded joint.

Figures 4 and 5 show the design of a typical calandria tube-to-tubesheet joint. Figure 4 shows the assembly before rolling. The tubesheet has a wide groove and two narrow grooves outboard of it. The calandria tube is located in the tubesheet bore. An insert is installed within the end of the calandria tube. The insert is made of stainless steel (type 410). The insert has a mating land to match the wide single groove in the tubesheet. During roll-expansion, the insert is expanded until the land on the insert forces the calandria tube material into the mating groove in the tubesheet. After all the clearances between the insert, calandria tube and the tubesheet are taken up, the tubesheet is further roll-expanded until the required reduction in the wall thickness of the insert is obtained and the material in the insert shoulder is forced into the two narrow grooves in the tubesheet. Figure 5 shows the joint in the roll-expanded condition.

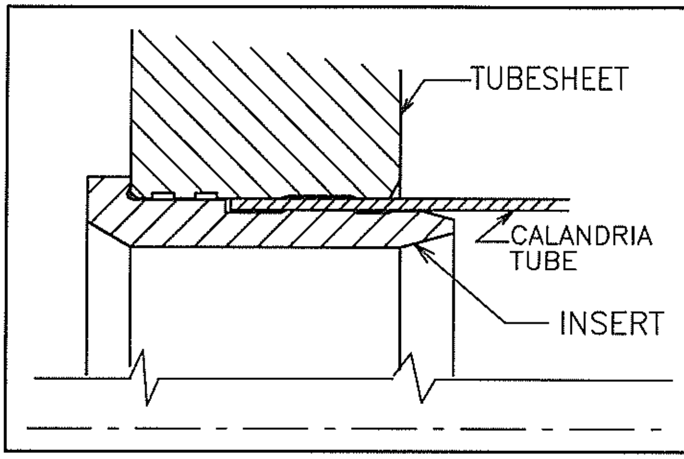


Figure 4: Calandria Tube-to-Tubesheet Joint – Assembly before Roll-Expansion

Operating Conditions

During its operating life, the inboard end of the joint is exposed on the outside to the moderator D_2O (at 70°C), and to the additives that are added to the moderator to control reactivity. The atmosphere inside the calandria tube consists of annulus gas (CO_2) and its radiolysis products. The joint is exposed to the thermal radiant heat from the pressure tube surface, which is at a temperature of approximately 300°C. The rolled joint is also subjected to neutron flux and alpha, beta and gamma radiations.

Design Requirements

The calandria tubes act as stays between the calandria end shields. Therefore, the joint must transmit, between the tubesheet and the calandria tube, the loads resulting from normal and accident conditions. The loads are axial, bending and thermal loads, and the loads due to in-reactor deformation of the calandria tube.

The joints are required to withstand pullout loads sufficient to cause failure of the calandria tube remote from the joint.

The joint is a part of the pressure boundary for the moderator system, and therefore must form a water-tight seal to prevent leakage of moderator into the annulus gas system.

The joint must perform reliably throughout its design life, so that its contribution to the reactor incapability can be shown to be almost zero. The joint must not require any maintenance, because it is inaccessible after the fuel channel is installed.

Applicable Codes and Standards

The joints are designed to the requirements of the Canadian Standards Association Standards CAN/CSA-N285.0-M91, CAN/CSA-N285.1-M91 and CAN/CSA-N285.2-M89, which also refer to the applicable rules in the ASME Boiler and Pressure Vessel Code, Section III.

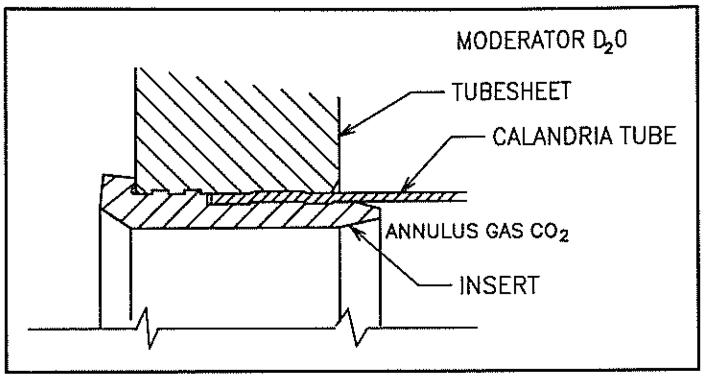


Figure 5: Calandria Tube-to-Tubesheet Joint – Assembly after Roll-Expansion

Design Evolution

Similar to other roll-expanded joint designs, the design of the calandria tube-to-tubesheet rolled joints has evolved through feasibility tests and developement and qualification programs test programs, in which more than 200 joints have been tested. The programs were formulated to ensure (a) that the qualification envelope covered the range of all variables, and (b) that, within the qualification envelope, the joint design met the design requirements.

Factors Affecting Joint Performance

The variables in the fabrication of a calandria tube-to-tube sheet roll-expanded joint are (a) the yield strength ratio (hardness ratio) of the tubesheet-insert combination, (b) degree of roll-expansion and (c) the dimensions of the mating components. Since the material properties of the tubesheet and insert are specified to be within a narrow range, the variation in the strength ratio is limited to the combination of the extremes in the achieved material properties of the individual components resulting from heat-to-heat variations. The effect of the variables on the joint performance are detailed in Reference 2.

Degree of Roll-Expansion

The degree of roll-expansion is specified as the reduction in the wall thickness of the insert due to roll-expansion. The inside diameter of the insert after rolling is used to calculate the reduction in the insert wall thickness. The joints are fabricated to achieve an increase in the insert diameter ("diametral wall reduction") of approximately 0.51 mm (0.020 in).

Production Roll-Expansion of the Joint

In contrast to the fuel channel installation, the calandria tubes are installed during the fabrication of the calandria at the manufacturer's shop.

Each calandria tube is trimmed to suit the distance between the calandria tubesheets at the specific lattice site. The dimensions of the tubesheet bore, the insert and the calandria tubes are measured to ensure their conformance with the requirements. The calandria tube is inserted through the lattice tube bore and is positioned in the bore of the tubesheet. The sleeve insert is installed in the calandria tube bore at the specified axial location. A refinery-type expander is used for the fabrication of the joint. The expander is set to achieve the required reduction in the wall thickness of the insert. During roll-expansion, the insert is held axially until all the radial clearances between the components are eliminated. The axial restraint on the insert is then removed and the roll-expansion is continued, thereby allowing the axial extrusion of the insert during its wall reduction. After the completion of roll-expansion, the inside diameter of the insert and the axial extrusion are measured. Each joint is subjected to a helium leak test.

The dimensions of the tubesheet bore, calandria tube and the insert are held within a narrow tolerance range, thereby allowing the option to roll-expand all the joints in a reactor to a standard inside diameter of the insert (after roll-expansion).

Operating Experience

No evidence of deterioration in the joint performance has been observed in any of the 20 000 joints in the operating CANDU commercial power reactors.

Individual calandria tubes have been successfully replaced since 1968, thereby confirming their ease of replaceability.

The programs in progress are addressing the development of the joints for the calandria tube designs that are being developed to meet the requirements of the next generation of CANDU reactors.

LINER TUBE-TO-END FITTING JOINTS

Joint Description

The liner tube is made from seamless tube manufactured in accordance with the requirements of ASTM-A268, Grade TP-410.

The inside diameter of the liner tube is 104 mm (4.09 in). The outside diameter of the tube, at the region to be expanded into the end fitting, is 112.7 mm (4.437 in). The end fitting body, at the location of the liner tube joint, has an inside diameter of 112.8 mm (4.442 in) and is about 25 mm (1 in) thick. The liner tube-to-end fitting joint in CANDU 6 reactors is a one-groove roll-expanded joint (Figure 6). The liner tube is roll-expanded to a nominal reduction of 7% in the wall thickness of the liner tube.

Operating Conditions

During operation, the liner tube joint is exposed to primary heat transport D_2O. The liner tube and the joint are not pressure boundary components.

Design Requirements

One of the functions of the liner tube is to locate and support the shield plug. The shield plug locates the fuel bundles in the fuel channel and it is held in position in the liner tube by a latch mechanism. To facilitate remote on-power fuelling, the liner tube joint must position the liner tube accurately, relative to the outboard (fuelling machine) face of the end fitting.

The liner tube joint must resist the axial loads imposed by on-power fuelling operations without any axial movement of the liner tube. The joint must be able to withstand, without failure, the pressure load imposed through the shield plug, in the unlikely event of the ejection of the channel closure. The joint must allow a smooth and unimpeded passage of the fuel. The joining process must not deform the flow holes in the liner tube.

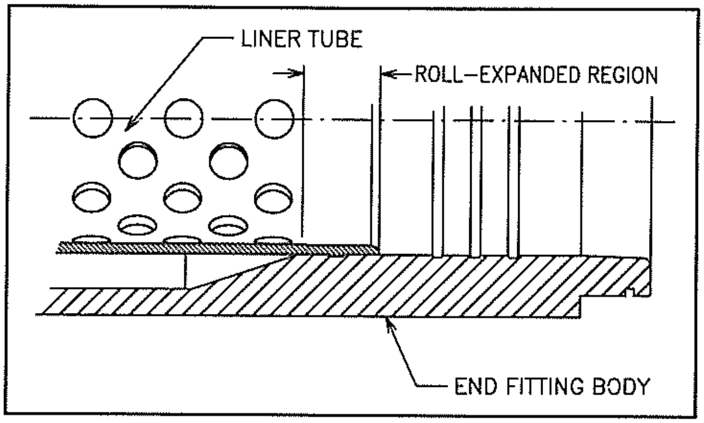


Figure 6: Liner Tube-To-End Fitting Roll – Expanded Joint

Development of the Joint

The liner tube joints were first used in Douglas Point NGS, which was the first CANDU (prototype) power reactor to use the fuel changing concept similar to that used in CANDU 6 reactors. The joint design was similar to the present design, except that two grooves were used.

The development program, which consisted of testing a number of joints, confirmed that (a) the strength requirements were met, (b) the axial extrusions in the liner tube were small enough to allow accurate positioning of the liner tube, and (c) the roll-expansion did not affect the end fitting or weaken the liner tube at the flow-hole locations.

The development tests were repeated during the design of the fuel channel for Pickering NGS A, the first commercial power reactor to use liner tube joints. The joint was a single-groove design. The joint was qualified by a test program similar to the earlier program described above.

Factors Affecting Joint Performance

The relative mechanical strengths of the liner tube and the end fitting body and the degree of roll-expansion affect the strength of the joint. The degree of roll-expansion, quantified by the reduction in the wall thickness of the liner tube, must be optimized to attain the required strength while resulting in a minimal, if any, deformation of the liner tube.

Production Roll-Expansion of the Joint

The liner tube is roll-expanded into the end fitting by the manufacturer of the end fitting. The roll-expansion procedure, tooling and personnel are qualified by the fabrication of three acceptable pre-production joints. Prior to roll-expansion, the liner tube is so located that its final post-roll position would conform to the specified requirements. Each liner tube is custom-roll-expanded to achieve the specified reduction in the wall thickness of the liner tube. The reach of the expander is set to avoid any distortion of the flow holes during roll-expansion.

Each joint is subjected to (a) dimensional inspections, to assure that the required wall reduction is achieved and that the fuel passage is unimpeded, and (b) a visual examination.

Operating Experience

There are about 9 200 liner tube roll-expanded joints in operation and they have performed satisfactorily. They have not contributed to any reactor incapability.

FUEL CHANNEL ANNULUS BELLOWS-TO LATTICE TUBE JOINT

Joint Design

The bellows assembly, which seals the annulus between the end fitting and the lattice tube, is provided with a stainless steel (304L) ferrule at one end. The outside diameter of the ferrule is 197.2 mm (7.764 in) and its wall thickness is 4.47 mm (0.176 in). The ferrule is roll-expanded into the lattice tube (304L) at the fuelling machine tubesheet. The lattice tube inside diameter at the joint region is 187.5 mm (7.775 in).

Figure 7 shows the details of the two-groove roll-expanded joint. The joints are roll-expanded to a standard inside diameter to achieve a reduction of around 7.3% in the wall thickness of the bellows ferrule.

Operating Conditions

The joint is exposed to the annulus gas (CO_2) on the inside surface, and the outboard end is in the dry air between the fuelling machine tubesheet and the feeder insulation panels. The ambient temperature is about 260° C. The joint is in a low neutron flux and gamma radiation field environment.

Design Requirements

As a part of the bellows assembly, the joint must withstand the axial loads due to thermal changes, and the in-reactor elongation of the pressure tube and the torsional moment from the feeders. The joint must meet the leak-tightness requirements of the gas annulus system.

Applicable Codes and Standards

The joint is a part of the gas annulus system and is designed in accordance with CSA/CAN3-N285-0-M81, "General Requirements for Pressure Retaining Systems and Components in CANDU Nuclear Power Plants".

Development Tests

Pickering NGS A, unit 1, was the first CANDU reactor to use a sealed annulus gas system. The design featured a roll-expanded joint to connect the bellows assembly to the lattice tube.

The design was developed and qualified by a test program. The primary variable in the test program was the degree of roll-expansion: namely, reduction in the bellows ferrule wall thickness by roll-expansion. A number of joints were subjected to a dimensional inspection, to quantify the axial extrusions and the rotation of the bellows ferrule and the distortion of the ferrule and the lattice tube (tubesheet) during roll-expansion. Helium leak tests were performed in the as-roll-expanded condition. During the torsional resistance tests, the torsional moment was imposed on the joint, in steps. At each load increment, the torsional moment was unloaded and the joint was examined for any permanent rotation or damage. The axial strength of the joint was determined by pullout tests. A temperature-cycling test, with intermediate helium leak tests at the elevated temperature, was also performed. The development tests demonstrated that the joint design met the requirements.

Production Roll-Expansion of the Joints

In the reactors where the bellows to lattice tube joints are roll-expanded, annulus bellows are installed at the reactor site during the installation of fuel channels. The joints are roll-expanded to achieve a standard (roll-expanded) inside diameter of the ferrule. This diameter corresponds to a reduction of 7.3% $\pm$ 2.1% in the wall thickness of the ferrule, taking into consideration the dimensional tolerances of the interfacing components. The inside diameter at the joint is measured and recorded. On completion of the fuel channel installation, the gas annulus system, including the joints, is subjected to a pressure test.

Prior to production installation, pre-production joints are fabricated to qualify all personnel, tooling and the procedure. The pre-production joints are subjected to a leak test.

Operating Experience

The rolled joint design is used in sixteen reactors and has performed reliably.

FIXED END-STOP COLLAR TO LATTICE TUBE JOINT

In Bruce NGS A, Units 1, 2, and 3, the end fitting at the fixed end of the fuel channel was joined to the end shield using a fixed end-stop collar instead of the bellows assembly.

The end-stop collar was made of carbon steel to the requirements of ASTM A105 or ASTM A106. The collar was joined to the lattice tube using two roll-expanded joints. The joint design is shown in Figure 8. The outboard joint, location "A" in Figure 8, is a two-groove joint. It is roll-expanded to achieve a nominal reduction of 7.3% in the wall thickness of the end-stop collar. The joint provides leak-tightness and axial strength. At the inboard location, "B", an ungrooved joint is roll-expanded to attain a nominal reduction of 2.5% in the wall thickness of the end-stop collar. This results in a residual interference between the components and imparts bending strength to the joint to withstand the loads resulting from supporting the fuel channel.

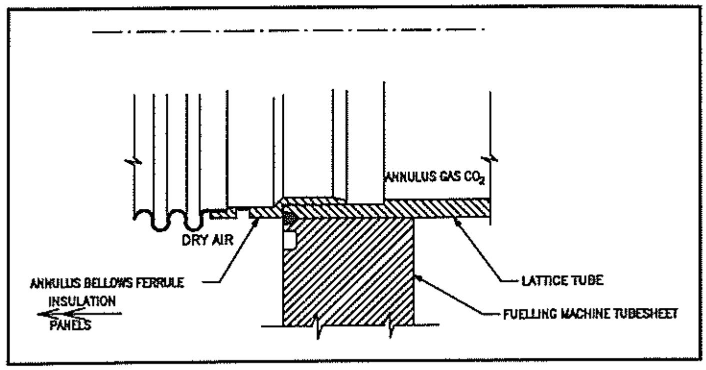


Figure 7: Annulus Bellows to Lattice Tube Roll - Expanded Joint

Operating conditions are identical to those of the annulus bellows-to-lattice tube joints. In addition to the design requirements of the annulus bellows joints, the end-stop collar joint must withstand the vertical loads and bending moments resulting from supporting the fuel channel.

The joint design was qualified by development tests. The joints were subjected to a combination of axial, bending and torsional loads and temperature cycles, and leak tested.

During production installation at reactor site, the end-stop collar was accurately positioned in the lattice tube. The outboard joint at location A was roll-expanded before roll-expanding the inboard joint at location B. The joints are fabricated to obtain standard inside (roll-expanded) diameters of the end-stop collar at their respective locations. A leak test was performed.

The 1 440 joints, which are in service, have been free of any malfunction.

JOINTS IN FLUX DETECTOR GUIDE TUBES

Joint Design

Figure 9 shows one of the designs of the joint between the stainless steel tube and the Zirconium alloy tube in a guide tube assembly for the flux detector. The Zircaloy 2 tube, 20.8 mm (0.82 in) outside diameter x 1.1 mm (0.043 in) wall thickness, is connected to the 304L outer hub 33.5 mm (1.34 in) outside diameter x 21 mm (0.827 in) inside diameter.

Three grooves are machined at the inside surface of the outer hub. Prior to final machining, the bore of the outer hub is work-hardened. The Zircaloy 2 tube is roll-expanded to 13.5% reduction in its wall thickness.

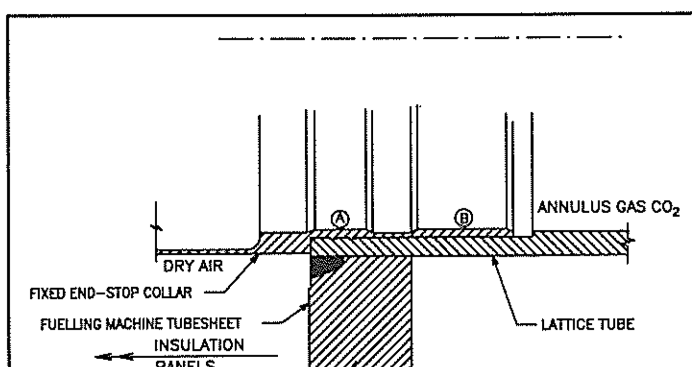


Figure 8: End-Stop Collar to Lattice Tube Roll - Expanded Joint

Operating Conditions

On the outside surface the joint is exposed to D_2O moderator at about 70° C. The inside surface of the joint is exposed to helium. The joint is subjected to the external pressure due to the moderator system.

Applicable Codes and Standards

In reactors where the guide tubes form part of the reactor containment boundary (during the maintenance of the flux detectors), the joint is designed to the requirements of the ASME Boiler and Pressure Vessel Code, Section III, Class 2.

Joint Development

During the development tests to qualify the joint design, the joint was thermally cycled 1000 times between 38°C and 121°C and the joint remained helium leak-tight. The strength of the joint was equivalent to that of the Zircaloy 2 tube.

Production Roll-Expansion of the Joints

The joint is fabricated by the manufacturer of the flux detector assemblies.

Prior to roll-expansion, the components are positioned so that the final assembly will meet the specified dimensional requirements. A refinery-type expander is used. Similar to pressure tube and liner tube joints, the guide tube joints are custom-roll-expanded. The joints are subjected to a helium leak test with the external helium pressure. A specified axial tensile load is applied to the joint during the helium leak test. The helium leak rates of the joints must meet the specified requirements.

Operating Experience

The guide tube joints have performed to their requirements in the commercial power reactors. They have not contributed to any reactor incapability.

OTHER APPLICATIONS OF ROLL-EXPANSION

Roll-expansion has also been used during the fabrication of the end shield, to generate interference between components to eliminate crevices and thereby avoid crevice corrosion.

During gas annulus tubing installation, the process is used to prevent any rotational movement during welding.

CONCLUSION

The conceptual designs of the above joint designs were initiated to address well-defined requirements. Their evolution has been based on years of experience. They were developed and qualified by extensive and well-controlled test programs using full-scale components, and by analyses.

The components are manufactured to stringent specifications. The component manufacture, and their assembly and joining processes are subject to strict quality control. Prior to production of the joints, the personnel, the procedure and the tooling are qualified by mandatory qualification tests using full-scale components. The post-service surveillance examinations of the joints are undertaken to evaluate their fitness for service.

The above measures have made the roll-expanded joints one of the reliable design elements in the design of CANDU commercial power reactors. The mission of the on-going development of the joint concepts for the next generation of CANDU reactors is to conform to this high performance standard.

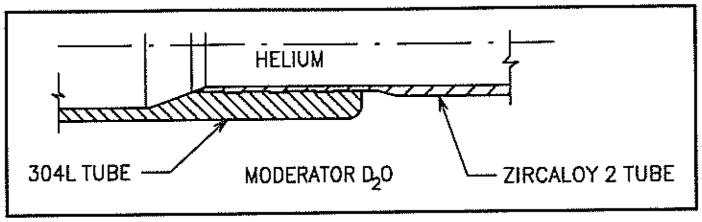


Figure 9: Flux Detector Guide Tube Roll – Expanded Joint

ACKNOWLEDGEMENT

This paper summarizes the work performed at GE Canada, Westinghouse Canada (Canadian Westinghouse Company Limited) and AECL since the 1960s. The programs were sponsored and funded by Ontario Hydro and AECL and the CANDU Owners Group.

The authors are indebted to their co-workers (too numerous to name), whose input was invaluable in the preparation of this paper.

This paper is dedicated to E.H. Farris of GE Canada. His contribution, during his entire professional career (thirty seven years!), to the design, development, testing and production of roll-expanded joints is well-respected and appreciated in the CANDU fraternity. His knowledge, experience, insight and diligence have been an inspiration to those associated with the CANDU reactor design.

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Final Call for Papers

Second International Steam Generator and Heat Exchanger Conference

13-15 June 1994, Toronto

The organizers of the 1994 CNS Steam Generator Conference have agreed to extend the deadline for papers until shortly after this issue of the CNS *Bulletin* is published.

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Licensing CANDU 3 in the United States

L. Rib[1] and D. Pendergast[2]

Ed. Note: *In the last issue of the CNS* Bulletin, *Vol. 14 No. 2, there was an article and editorial on AECL's activities towards having the CANDU-3 design licensable in the USA. The following article, extracted from a paper presented to an IAEA Technical Committee meeting held in Toronto in June 1993 provides more detail on the progress of US NRC reviews.*

Background

Atomic Energy of Canada, Ltd. (AECL) has an ongoing effort to extend the proven and reliable CANDU technology for a system especially designed for future electric utility markets. This system, designated CANDU 3, is a 450 megawatt plant that incorporates such features as modular construction, utilization of natural uranium fuel, 37 month construction schedule, computer controlled operation, high availability (through the use of on-line refueling), a long design lifetime with replaceable components, and other features that will contribute to improved safety and reliability.

It is our hope that we can share in what we believe to be an emerging market for nuclear power plants which will materialize before the year 2000 in the United States and throughout the rest of the world. To achieve this objective, we recognize that we must receive a standard design certification approval and ultimately a construction license from the U.S. Nuclear Regulatory Commission. It will also be necessary to establish the proper infrastructure in the U.S. which would make it possible to deliver a complete system utilizing the CANDU reactor as an American-made product based upon Canadian technology. A 10-year strategic plan has been prepared that calls for the establishment of an organization with the capability and expertise to develop, to deliver and service a system to a U.S. utility or other buying organization.

In December of 1988, AECL Technologies (AECL T), a division of AECL Incorporated, an American firm, was created specifically for this purpose with headquarters in Rockville, Maryland. A. Douglas Hink was recently appointed Vice President and General Manager of the U.S. operations. The new firm has a complement of about a dozen employees and consultants who function as a design licensing team working in parallel with the AECL Canadian design team now completing the generic CANDU 3 design.

In a letter dated May 25, 1989, AECL T informed the Nuclear Regulatory Commission of its intent to seek design certification of the CANDU 3 under the provisions of 10 CFR Part 52. Since that time, we have briefed the Commission staff, the ACRS and other groups within the NRC. There have also been visits by NRC staff to Canada and communication between the NRC and the Atomic Energy Control Board.

In addition to licensing related activities, we are also involved in what we term "the Americanization" of the CANDU design. We have conducted meetings with EPRI and the DOE and are developing a base of knowledge which will enable us to understand the requirements which both those organizations have established for their advanced light water reactor programs. It is our intent to comply with the applicable requirements that are established by EPRI and the U.S. utilities for future reactor plants.

We are also in discussions with a number of U.S. firms who have shown interest in joining with us as part of our infrastructure team. Our long-term objective is to be able to deliver a complete CANDU plant built in the United States with as much U.S. content as possible. We would hope that at some date in the future AECL T would be considered in the same light as any U.S. vendor and that we would be in a position to provide all the services and equipment needed to sustain ongoing operation of nuclear power plants. To do this we will need to combine with companies that have specific expertise above and beyond our own.

Licensing Program Progress

Prior to 1992, there were a number of important submittals made to the NRC beginning with our letter of intent to apply for Standard Design Certification (SDC) dated May 28, 1989. Then, in response to an NRC request dated July 6, 1989, AECL T submitted the following reports to NRC:

- CANDU 3 Conceptual Safety Report
- Canadian Codes & Standards Used in the CANDU 3 Design
- CANDU 3 Conceptual Probabilistic Safety Assessment
- CANDU 3 Technical Description
- CANDU 6 Operating Policies & Principles
- AECB Regulations
- Draft Licensing Review Basis (LRB) Document

For the purpose of familiarizing the NRC with technical aspects of CANDU systems, which are unique as compared to light water reactors, we submitted a series of technology background reports. There were six reports submitted during this period:

- Canadian Tritium Experience
- The Technology of CANDU Fuel Channels
- The Technology of CANDU On-Power Fueling
- The Technology of CANDU Loss-of-Coolant Analysis
- The Technology of CANDU Shutdown Systems
- The Technology of CANDU Source Term Calculation

In April of 1991, the NRC decided to perform a Preapplication Review for the CANDU 3 instead of continued development of the LRB D and we are currently proceeding with this objective.

In addition to the documented information listed above, AECL T has participated in a number of topical and informational meetings with the NRC Licensing staff, the ACRS

1 AECL Technologies, Washington, D.C.
2 AECL CANDU, Mississauga, Ontario

and the NRC-Research staff. Additional information was submitted to the NRC Licensing staff as a part of AECL T's proposed "up-front dialogue on potential licensing issues" during the Preapplication Review during 1992, including the following:

- CANDU 3 Design Comparison with the NRC General Design Criteria
- Comparison of CANDU 3 with NRC Positions for Evolutionary LWR Certification Issues
- Comparison of NRC Licensing guidance for Safety--Related Structures, Systems and Components with the CANDU 3 Design
- A set of technology reports discussing a selected number of potential licensing issues. (AECL T proposes to initiate early dialogue on these design aspects which are related to CANDU technology developments)
- A report identifying specified elements of the CANDU 3 experimental database in support of accident analysis.

In early 1993 the NRC was subject to funding reductions which led to a proposed sharp curtailment of advanced reactor pre-application review activity. (Until recently, CANDU 3 has been included in the advanced reactor category for the pre-application review phase.) AECL T has responded to this change of direction by submitting a letter of intent to apply for standard design certification in about one year.

The licensing program undertaken by AECL T is beginning to receive significant input and feedback from the NRC.

A recent NRC staff recommendation to the NRC commissioners states that CANDU 3 should be considered an evolutionary heavy water reactor which does not require a prototype for standard design certification.

The NRC's Office of Nuclear Regulatory Research (NRC/RES) has initiated several studies related to the CANDU 3 and other advanced reactors. The purpose of these independent studies is to aid the development of staff guidance for the licensing process. Two studies are exclusively related to the CANDU 3 reactor.

- Idaho Nuclear Energy Laboratory (NEL) "CANDU 3 Transient Analysis." This involves thermal-hydraulic and physics analysis for loss of coolant and other transients and includes an evaluation of the CANDU experimental database.
- Oak Ridge National Laboratory (ORNL) "CANDU 3 System Research." This involves studies of failure mode and effects analysis for the CANDU 3 reactor.

Three research projects pertain to several advanced reactors. The CANDU 3 portion of these research projects will be conducted early in the program.

- SANDIA National Laboratory (SNL) "Source Term Analysis." The first part of the program focuses on determining what the vendors have done to establish the source term. Later on the program will address the need for independent assessment of the source term.
- Oak Ridge National Laboratory (ORNL) "Severe Accident Analysis." The first part of the program establishes what the vendors have done to delineate severe accident analysis. The project will address the need for independent assessment of severe accidents.
- Argonne National Laboratory (ANL) "Regulatory Support for Advanced Reactor Program." This evaluates

Issue	NRC Staff	ACRS
Accident Evaluation	New regulations needed. Propose to develop an approach to accident evaluation for CANDU 3 in common with advanced reactors. Events for evaluation to be chosen by staff deterministically.Categories established on frequency basis. Consequence acceptance limits to be established for each category. Lower probabilities than current design basis included. Events equivalent to current design basis to be analyzed conservatively.	Agrees with the general approach to new regulations. Believes the staff should establish quantitative guidelines and criteria for accident selection and evaluation at an early stage as an alternative to deterministic selection.
Source Term	A different method of calculating source term is needed.Staff propose to develop a set of source terms for design basis and core damage accidents. The source terms will be calculated on a mechanistic basis which takes into account expected cladding, fuel and core damage based on best estimate analysis.	Basically agree with the staff approach and ask the staff to take into consideration developing revisions to the TID-14844 source term for light water reactors.
Containment Performance	A new standard based on functional performance is proposed. Onsite and offsite release limits for the various frequency categories to be developed must be met. "The staff proposes to require the preapplicant to postulate a core damage accident as a containment challenge event to demonstrate that containment integrity is maintained for a period of 24 hours after the onset of core damage."	Agree with this approach and are interested in seeing the list of postulated core damage accidents.
Positive Void Reactivity	"The staff concludes that a positive void coefficient should not necessarily disqualify a reactor design. The staff is proposing to require that the PRISM and CANDU 3 preapplicants analyze the consequences of events(such as ATWS, unscrammed LOCAs, delayed scrams,and transients affecting reactivity control)" The staff will take into account the risk perspective of the CANDU 3 design posed by the dual safety shutdown systems.	The ACRS "agree with the staff that the existence of a positive void reactivity coefficient is a significant concern, but that it should not necessarily disqualify a reactor design." The staff are asked to define the criteria which would be used to judge whether the consequences of an accident which would be aggravated by a positive void coefficient are acceptable or satisfactorily mitigated.
Control Room and Remote Shutdown Area	The staff do not agree that new regulations are needed to govern the design of control rooms. They believe the main control room should be seismically qualified and remain the main control centre after accidents.They will apply current standards for LWR's till new policy is developed for passive LWR's.	The ACRS disagrees with the NRC staff position and believes that applicants should accept the burden of demonstrating that a proposed design is satisfactory. The staff are asked to establish acceptance criteria.

Table 1 NRC Staff Position on Selected CANDU 3 Policy Issues (see Reference 2)

the application of codes and standards for reactor construction and the need for revised technical standards.

AECL T and AECL are assisting the NRC/RES to obtain information for their studies.

The NRC developed a Policy Statement on the regulation of advanced nuclear power plants in 1986. Additional interpretation of the Policy was published along with the policy, in 1988 in NUREG – 1226.[1] This preceded AECL T's letter of intent to apply for Standard Design Certification. CANDU 3 was subsequently included in an NRC review of policy issues pertaining to advanced reactors (PRISM, MHTGR, and PIUS). Some of the information provided by AECL T was factored into the review. The findings were published this spring (SECY-93-092).[2]

A number of other issues were reviewed. The reviews were undertaken with the guideline that existing LWR regulations should be followed where possible and new requirements should move toward performance standard regulations and away from prescriptive regulations. Designers requesting pre-application reviews had been encouraged to propose new criteria and novel approaches for design evaluation.

Table 1 summarizes the NRC analysis (SECY-93-092) for five issues pertaining to CANDU 3 which propose deviations from current light water reactor regulations. The summary shows major points of difference between regulations needed for CANDU 3 and LWR's. Some issues (e.g. Source Term and control room habitability) strongly reflect a need for new regulations for existing reactors as well as for reactor technology new to the NRC. Most of the issues are open ended at this time. A direction has been set to establish regulations which are less prescriptive than current regulations. We believe that this direction will lead to general performance requirements which allow a balanced and equitable evaluation of all applicants for Standard Design Certification.

Our prelicensing program continues with frequent and extensive contact with the NRC and the DOE national laboratories under contract to them. We are in the process of preparing a preliminary Safety Analysis Report for submission along with an applicant for Standard Design Certification in 1994. We are hopeful that at such time as we present the completed design for review for certification, NRC staff will be familiar with the unique aspects of CANDU technology and will have established acceptance criteria for the review.

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Nuclear Liability Goes to Court

A major and likely protracted legal battle began October 12 in an Ontario Court in Toronto. Energy Probe, the City of Toronto, and Sister Rosalie Bertell are challenging that the Nuclear Liability Act is unconstitutional.

The official defendant is the Attorney General of Canada, with Ontario Hydro and the New Brunswick Electric Power Commission as intervenors supporting the federal government. Senior officials of the Atomic Energy Control Board, Atomic Energy of Canada Limited, Health and Welfare Canada will appear as expert witnesses as will Dr. A. Birkhoffer, head of GRS in Germany and Sir Richard Dolling of the U.K.. Ontario Hydro chairman Maurice Strong has been subpœnaed to appear.

The Nuclear Liability Act was passed in 1970 but not proclaimed for some time thereafter and applies to designated nuclear facilities. In the case of nuclear power plants the NLA requires the "operator" (owner) to carry commercial third party liability insurance of $75 million and provides the federal government the power to establish a commission to deal with situations where the claims could exceed that amount in the case of a nuclear incident. Operators are absolutely responsible for any injury or damage resulting from an event, without any need for the injured party to show fault or negligence. Suppliers of equipment are absolved of any liability.

Most countries with nuclear power programs have similar nuclear liability laws but in most cases the requirement for commercial insurance is much higher, e.g., in the U.S.A. it is now $6.6 billion.

The plaintiffs charge that the NLA is "ultra vires" in two accounts with respect to the Constitution Act 1867 (former BNA Act) – regarding property rights and facilities for the production of electricity – which, they claim, are in the domain of the provinces.

Four charges are made under the Charter of Rights where they argue that the NLA:

- decreases the cost of nuclear power
- reduces the incentive to take care and to make safety expenditures
- limits compensation to potential victims

and, thereby increases the risk to the public.

Those involved expect that the focus will be on the charges that the NLA decreases safety since there are precedents to support federal jurisdiction in things nuclear. Utility representatives contend that their large investment ensures that safety is a high priority in the design and operation of nuclear plants.

Energy Probe and associates (some of whom have since severed their involvement) first raised their charge in 1987 but it was not until last year that the Supreme Court gave permission for the case to proceed.

Energy Probe has sent out appeals for money to support its challenge, stating that they have disclosed "startling revelations" during the past two years of pre-trial studies, and promising "shocking testimony about nuclear safety".

The trial is taking place in Toronto and is scheduled to run until the end of January (although some participants anticipate that it might continue for six months).

Nuclear Engineering at the University of Toronto

The teaching of Nuclear Engineering at University of Toronto was initiated under Dean R.R. McLaughlin (Dean of Engineering) in 1957 with the hiring of Prof. D.G. Andrews. Space was found in Chemical Engineering and construction of a subcritical natural uranium heavy water assembly was started in December 1957. The subcritical reactor was completed and licensed shortly after Easter 1958, and was officially opened by the Hon. Leslie Frost, Premier of Ontario in June 1958. Prof. R.E. Jervis took up his position in Chemical Engineering in May 1958. Initially teaching in Nuclear Engineering was only for graduate students and developed into a 23-unit programme taught over two years leading to a M.A.Sc. or Ph.D. degree.

Undergraduate teaching in the nuclear area began as a mainly theoretical option in Engineering Physics, under the late Prof. B. Davison of the Department of Physics. This was progressively broadened to include more applied nuclear content in the Engineering Physics curriculum during the 1960s. The general introduction of undergraduate technical electives in Engineering in the late 1960s allowed the introduction of nuclear engineering courses more broadly to students in the mechanical, chemical, electrical, civil and metallurgical disciplines. This resulted in teaching involvement of faculty members in other departments, whereas prior to this the teaching load had fallen almost entirely on Chemical Engineering. During this period the Nuclear Option was combined with the Thermal Power Option operated by Prof. F.C. Hooper to produce a Nuclear and Thermal Power Option in the third and fourth years of what became known as Engineering Science.

At the close of the 1960s the teaching pressure led to the addition of a further faculty member, Prof. J.S. Hewitt, and to the introduction of Adjunct Professors. J.H. Aitken, R.E. Kay, M.H. Roshd, J.A. Sovka and K.Y. Wong became the first of a continuing line of senior men from AECL, Ontario Hydro and the Ontario government who have provided up-to-date teaching in specialised areas of the nuclear field.

Additions to the nuclear equipment available have included two Gammacells (^{60}CO irradiation units) and the acquisition of a low power enriched uranium reactor (SLOWPOKE) in 1971. This reactor, now on its second core (SLOWPOKE-II) continues to be the work-horse for activation analysis, and the radiochemistry programme at University of Toronto, providing also some labs for nuclear engineering students, both at undergraduate and post-graduate levels.

Teaching of the NT Option in Engineering Science and the Nuclear Electives for other disciplines continued through the 1970s with progressively more of the teaching load being taken up by other departments. In the graduate teaching area, interest in plasma and fusion reactor studies developed at the Institute for Aerospace Studies under Profs. P.C. Stangeby and A.A. Haasz, and teaching in these areas is now exclusively in Aerospace. Student interest in the NT Option continued to be high (▷ 20 students in 3rd and 4th years) until the beginning of the 1980s when a steep decline ensued. This caused the University of Toronto in 1982 to pose the question as to whether or not Nuclear Engineering training and research should be continued, and a task force was set up to answer this question. By the middle of this decade numbers have increased but are still low (total still in single digits). The question of continuation of Nuclear Engineering training in its present form has still not been finally settled. Students registered for the nuclear elective courses have also declined in this period, although not to the same extent as the decline in the NT Option. However, during the initial 20-25 years of the nuclear programme, totals of about 80 post-graduate students and 250-300 undergraduate students graduated from programmes in which they specialised in Applied Nuclear Science and Nuclear Engineering.

The situation changed somewhat in the 1980s with the creation on December 20th, 1983, by Dean G.R. Slemon of the Centre for Nuclear Engineering, under the Chairmanship of Prof. O.J.C. Runnalls, Professor of Energy Studies, and supported by a total of nine companies from the Nuclear Industry. The aim of the Centre was to coordinate and encourage teaching and research in the nuclear area throughout the University, and to encourage University-Industry ties. Its inception was a response to the recommendations of the Task Force, set up in 1982. As a further result of these recommendations two new faculty positions were authorised to replace Prof. D.G. Andrews, Dept. of Chemical Engineering, who had retired, and Prof. D.B. Cherchas, Dept. of Mechanical Engineering, who had moved to another university. The first was occupied by Prof. R.A. Bonalumi and the second by Prof. A.N. Sinclair. In July 1986 Prof. M. Kawaji joined the Dept. of Chemical Engineering and Applied Chemistry to replace Prof. R.A. Bonalumi who was felled by a debilitating illness in December 1984.

At the end of the first five year cycle of the Centre for Nuclear Engineering, further support from a total of eight companies within the Nuclear Industry permitted a successful application to NSERC under its University/Industry Research programme for the establishment of three Industrial Research Chairs in Nuclear Engineering. The Senior Chair, Prof. B. Cox, joined the Dept. of Metallurgy and Materials Science on Jan. 1, 1989, at the commencement of the new programme, and took over the Chairmanship of the Centre for Nuclear Engineering from Prof. O.J.C. Runnalls on his retirement on June 30, 1989. The two junior chairs in the Dept. of Chemical Engineering and Applied Chemistry and the Dept. of Mechanical Engineering were filled about a year later in mid-1990 by Professors G.J. Evans and J. Mostaghimi-Tehrani, respectively. The result of these changes has been to convert the Centre for Nuclear Engineering into a research based centre with its own programme of sponsored research, in addition to its previous functions. The encouragement of students to take an interest in Nuclear Engineering continues to be a primary aim.

Monitoring CANDU Service Water Discharge for Tritium

J.M. Cuttler[1] with N. Mina, L. Swami, and F.A. Ely[2]

Abstract

Following a large release of tritiated heavy water through a leak in a moderator heat exchanger, a continuous-flow radiochromatograph detector system was evaluated for monitoring tritium in service water. It consists of a liquid scintillation flow cell between matched photomultiplier tubes, with coincidence circuitry for maximum efficiency and low background. With a scintillant to sample ratio of 1:2 and a combined flow of 3.8 mL/min, the background is 180 CPM with prefiltered service water. The monitor responds with 4000 CPM within 8 min to a tritium concentration of 5 μCi/L. This alarm level is adequate to detect a moderator leak of only 36 mL/min into the service water.

Introduction

CANDU reactors employ heavy water for moderating neutrons and for transporting heat from the fuel to the steam generators. Five percent of the fission energy is deposited in the moderator. The moderator water is pumped through two heat exchangers to transfer this energy to a flow of service water from the ultimate heat sink (river, lake or ocean). In the case of the Pickering NGS reactor unit, this service water flow is 2.8 Mg/s or 168,000 L/min from Lake Ontario.

The neutron flux creates tritium in the moderator, and when it exceeds ~ 20 Ci/L, heavy water is removed for tritium extraction. If a leak developed in one of the heat exchangers, precious heavy water would be lost and tritium would be released to the environment.

This is precisely what happened at Pickering NGS in reactor unit No. 1 on Sunday, August 2, 1992. A piece had broken off a strainer some time earlier and had been abrading some tubes in one of the two heat exchangers. Suddenly, at ~1:30 a.m. EDT, one tube cracked and began to release a flow of heavy water. The leak was identified when the control room operator on duty conducted a routine check of the control panel at 5:50 a.m. and noticed a significant decrease in the moderator system inventory. The leak search included analysis of the moderator cooling (service) water, which indicated the leak and led to reactor shutdown and subsequent termination of the discharge at 7:30 a.m. By then an estimated 2,600 L of D_2O, worth CAN$1.2 million and having a tritium content of 21 Ci/L, was released to the lake.

The amount of tritium released was about 3 percent of the monthly derived emission limit (DEL). This limit is the calculated amount of radioactive material that, if released from the station each month for a year, would result in a radiation dose to an individual living at the plant boundary, equivalent to the maximum annual dose allowed for members of the public. Ontario Hydro's policy is to control releases to less than 1% of the DEL.

Notification of the release to Emergency Planning Ontario resulted in the temporary closure of nearby water treatment plants. Although the hazard to the public was minor, the incident became a major media event. Anti-nuclear activists clamoured about the release of radioactivity and demanded closure of the entire station. The Atomic Energy Control Board regarded this heavy water leak as a serious event and began to review equipment and procedures in place to ensure early detection of leaks in the future.

Corrective Measures

The standard procedure for monitoring emissions had been to take a sample of the service water discharge, four times a day, and analyze it for tritium by the liquid scintillation technique. This incident led to the realization that the periodic sampling procedure was inadequate to control releases during abnormal events. Simply increasing the sampling frequency would be too laborious for rare events.

The station decided that the proper approach would be first to prevent future occurrences by dealing with the root cause, the broken strainer. A program was instituted to inspect all the service water strainers to confirm their fitness for service. Then an alarm was installed on moderator inventory level to provide warning of a moderator inventory leak. Finally, as a backup measure for "defence in depth," an on-line tritium monitor was evaluated. It would measure the tritium concentration in the service water and alarm if the target emission limit was exceeded.

Tritium Monitor

Just prior to the event, Operations staff from Bruce NGS "A" and "B" had visited a well-established supplier of analytical equipment and had identified a continuous-flow radiochromatograph detector system which seemed promising for monitoring tritium leakage into the boiler feedwater system. They obtained a system for evaluation and informed others of their potential application. It became immediately apparent that this compact scintillation detector system, which had been developed for low-cost radio-HPLC analysis, could also be used as a continuous monitor of tritium in CANDU service water discharges.

A visit was quickly arranged with the local representative to explain the need and request urgent delivery of a suitable system for evaluation. The supplier recognized the potential market and responded favourably.

The monitor consists of a thin liquid scintillation flow cell between 2 inch, matched photomultiplier tubes with coincidence circuitry for maximum efficiency and low background. The technology is well documented in the literature.[1,2,3] In this system, a multichannel pulse-height analyzer is employed for precise data acquisition, with pretest windows for tritium, C^{14} and other beta emitters. A microcomputer controls the system operation, analyzes and stores the

1 AECL CANDU, Mississauga

2 Ontario Hydro, Pickering NGS

data, and provides the alarms. The data can be printed/plotted and also transferred to another computer or data logger for further processing and storage.

The equipment provided included a computer-controlled pump, with a 10 micron filter, to draw a constant sample flow from the service water discharge line. The designated technician and the staff responsible for environmental monitoring were trained to use the system and they proceeded to test different samples of tritiated water in the Chemistry Lab.

A 2.5 mL liquid flow cell was selected for high sensitivity, and the scintillant to sample flow ratio was set to 1:2 to reduce consumption of the Ultima-Flo™ M scintillant (non-toxic and biodegradable). A combined scintillant and sample flow of 3.8 mL/min was chosen.

The average efficiency measured is 39.6%, and the minimum detectable activity is 0.049 μCi/L.

A response of ~7100 CPM is measured for a tritium concentration of 9.1 μCi/L. The background is ~180 CPM when prefiltered service water is used. Since the required alarm level is 5 μCi/L, this monitor has more than adequate sensitivity for this application.

The measured response time (10 to 90%) was less than 8 min, using 2 metres of sample tubing.

A concentration of 5μCi/L corresponds to a 4×10^6 dilution of 20 Ci/L moderator water. This alarm level is adequate to detect a leak of ~36 mL/min into the service water flow from one reactor unit.

Future Plans

It is recognized that conditions at the outfall monitoring station will be less than ideal, so Pickering NGS is constructing a temperature-controlled room that will maintain reasonable conditions during the cold winter. Prefiltering will be used on a small branch of the service water flow, prior to extracting the flow to be measured.

The monitor will send an alarm to the control room. The data will be downloaded and examined routinely, and calibrations will be performed at appropriate intervals. If a decline in sensitivity is noted, the flow cell will be replaced and cleaned (off line). Long-term testing in the field may reveal contamination problems, such as those identified by Hofstetter and Wilson in a similar application at Savannah River. (They used 0.1-0.25 mm scintillator bands in a U-tube flow cell).[4]

Operating experience will determine whether this technology is appropriate for this application. If successful, this type of tritium monitor will likely be installed in other CANDU stations.

Acknowledgements

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The authors would like to thank Canberra-Packard Canada for providing the Radiomatic FLO-ONE/Beta Model A-140 detector system for this evaluation.

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Miscellany

Ontario Hydro to supply tritium to JET*

Ontario Hydro has concluded an agreement with the Joint European Torus (JET) in Abingdon, England, under which Ontario Hydro has contracted to supply JET with up to 90 grams of tritium (about 900,000 Curies), between now and the end of 1996. The agreement, completed in March of this year, includes a provision that Ontario Hydro will take back tritium from JET at the end of the project. Under local planning approval, the JET site is to be returned to "green field" conditions, and no radioactive material may remain on the site beyond a specified time. Some of the tritium returned to Canada will be in the oxide form as tritiated light water. CFFTP will coordinate the take-back operations on behalf of Ontario Hydro.

Ontario Hydro also has an agreement with Kernforschungszentrum Karlsruhe GmbH (KfK) in Germany to supply up to 200 grams of tritium over 10 years for the new tritium laboratory at KfK. Together, the tritium supply contracts for JET and KfK will earn export revenues well in excess of 5 million dollars. Ontario Hydro also supplies tritium for pharmaceutical research and to Canadian manufacturers of self-luminous lighting.

JET will use the tritium from Canada in an extended series of deuterium-tritium (DT) fuelling operations in the JET tokamak fusion research machine. The DT tokamak experiments are currently scheduled to take place throughout 1996. Deliveries of tritium may begin as early as spring 1994.

The tritium will be supplied from Ontario Hydro's Darlington Tritium Removal Facility (DTRF). By June this year, tritium yield to date from this facility totalled 5.7 kg. Uninterrupted tritium yield rate for the DTRF is 2.5 kg per year.

* Reprinted from *Fusion Canada*, published by the National Fusion kProgram whose program office is at the Chalk River Laboratories, Tel. (613) 584-8036.

Simulation Conference – Summaries

Ed. Note: The last issue of the CNS Bulletin, *Vol. 14, No. 2, included a short review of the 14th International Conference on Simulation Methods in Nuclear Engineering, which was held in Montreal, June 2 to 4, 1993.*

Inspired (or pushed) by conference co-chairman Hong Huynh, the various session chairpersons prepared summaries of their respective sessions. For those unable to attend, and as a quick review for those who did, these are presented below.

Full proceedings of the conference will be available from the office of the Canadian Nuclear Society (Tel. 416-977-7620; FAX 416-979-8356).

Plenary Session

Chairperson: Jean-Claude Amrouni

The first speaker M. François Boulot from Électricité de France gave a very interesting overview of the model development that are presently underway at EDF in the thermohydraulic area showing the emphasis on multidimensional representation.

Mr. Ian Shepherd from Ispra, Italy gave a resume of the Phebus experiment, its complexity and the challenges that face the thermohydraulic representation of the experiment.

Prof. Sanjoy Banerjee from the University of California in Santa Barbara gave a most advanced presentation on multiphase turbulent flows. The presentation highlighted the development areas of turbulent flows and their dependence upon computational power. In the next decade, the advent of very fast computers should enable this field to represent even more of the phenomena observed today in turbulent multiphase flows.

The first half of the plenary session was extremely interesting and the geographical disparity of the speakers added to the feeling of common and shared concerns within the international nuclear community for advanced simulation methodology.

Session 2A – Thermalhydraulics methodology

Chairperson: Sanjoy Banerjee

This session contained 5 papers, of which only 4 were presented, due to the absence of the author, Ashok Kumar.

The first paper in the session dealt with the TUF code developed at Ontario Hydro for best estimate thermalhydraulic calculations of CANDU nuclear plants. TUF has a reactor network capability, together with relatively well-developed control systems modelling, as well as options for one-fluid-fluid and two-fluid analysis and water-hammer analysis capability. The paper was presented by A.P. Masumdar of Ontario-Hydro, who described the code without being able to go into the details because of the short time available.

The next two papers dealt with modelling of the partial inventory thermosyphoning experiments. The most important aspect is the prediction of flow reversals and thermosyphoning breakdown.

The first paper, presented by Dr. P. Gulshani of AECL-CANDU with collaborators in Hydro- Quebec, presented a steady-state model to predict the thermosyphoning phenomena observed in the multi-channel RD-14, two-phase, high pressure experiments. There was considerable discussion as to whether a steady-state description such as this could capture the type of oscillatory behaviour seen in the experiments. However, the authors did argue, with some justice, that perhaps the breakdown of thermosiphoning was describable in there terms.

The next paper, by a group at Ontario Hydro, also attempted to analyze the RD-14 partial inventory experiments. The approach was an integrated lumped-parameter model that solves for the thermosyphoning flows under steady-state conditions. Some crucial assumptions had to be made in such a description, since relatively small fluctuations in the header-to-header pressure differentials could initiate flow reversals, and therefore it is difficult to ignore the oscillatory phenomena that is seen in such experiments.

Again, the main thrust was to determine the liquid inventory at which channel flow reversals might occur. There was considerable discussion as to what the oscillatory phenomena actually arose from after these papers were presented. It appeared to the Session Chair that there was insufficient understanding still about what was going on and how the liquid was distributed in the system.

The last paper was on a homogeneous, non-equilibrium critical flow model for critical flow through cracks presented by Dr. K. Crentsil, who spoke as a member of an Ontario Hydro team.

The model appears to have been validated against an extensive data base and also with various other codes, developed, for example, by the Electric Power Research Institute (PICEP). The agreement is generally good, within $\pm$ 25%. It should be noted that the main innovation in the Ontario Hydro developments are to allow predictions at low values of length-to-diameter ratio where nonequilibrium effects may be quite dominant. With high L by D ratios, frictional effects tend to dominate. The discussion centered primarily on clarifications of the computation procedure and the difficulties associated with using a Henry Fauske-type empirical correction factor for estimates of nonequilibrium critical flow.

All in all, the session was a lively one, and the papers were in general well presented and of substantial interest. The audience was particularly animated in discussions of thermosyphoning, a subject that is of obvious importance that calls for further understanding.

Session 2C – Moderator and Containment System

Chairperson: D. R. Pendergast

Ten to twenty years ago, containment analysts devoted most of their energy to the prediction of maximum pressure loading on containment. Analysis methodology focused on simple "point" models and one dimensional approximations of fluid flows within the containment structure. Mixing of all fluids was assumed within each of the one or more subvolumes of the containment model. Many tests were undertaken to ensure that the predictions provided adequate information for the design of containment structures.

Similarly moderator temperature was predicted with the assumption of mixing within the calandria vessel. This session marked a strong divergence from earlier methods. Four of the five papers presented were based on the development and application of more sophisticated analytic methods. These methods attempt to predict local variations of some fluid properties (temperature, component concentration) within the containment, calandria or another fluid flow situation important to reactor operation.

The first paper, an invited paper presented by Jack Travis of Los Alamos National Laboratory, summarized the features of the "Gasflow" code developed there. The code can simulate a wide range of problems from LOCA blowdown through to mixing and combustion of hydrogen. Jack closed by presenting a simulation of ignition started in one of two compartments. The flame then passed through an opening into a second compartment where the rate of combustion is greatly accelerated.

Kwok Tsang of AECL CANDU then discussed modelling of the response of a radioactivity detector, responsible for activating containment isolation, to radioactive materials passing by it in ventilation piping. This work was supported by Hydro Quebec and New Brunswick to help investigate spurious trips during CANDU 6 operations.

Jacek Szymanski presented some results for the MODTURC_CLAS code developed by Ontario Hydro, primarily to establish local moderator temperature. His study was focused on evaluating the variation in solutions resulting from more finely dividing the spatial resolution of the modelling. He also introduced the application of the code to two new problems. The local temperatures on the wall of a "T" junction was found in one study while the local concentration of chlorine in a discharge channel was the second new application.

Kyle Um of Ontario Hydro presented the results of a study that evaluated the role cooling fans play in the mixing of hydrogen that might be generated following a LOCA. He provided results for several scenarios with varying numbers of fans in operation.

The closing paper, presented by A. Rajakumar of the Indira Ghandi Centre for Atomic Research, applied three dimensional modelling to a problem of moderator cooling. In this case the performance of the moderator heat exchangers was evaluated. Modifications to the flow through the heat exchanger were being sought to try and maximize the cooling of the moderator. The overall goal was to avoid heating of calandria rolled joints beyond design limitations while maximizing reactor power output.

In summary, the papers presented mark a break from the past emphasis on determination of an appropriate design pressure. Development of methodology and computer improvements, perhaps helped by a lack of emphasis on new designs in recent years, has allowed attention to more subtle simulation problems in the containment and moderator systems.

Session 3A – Thermalhydraulics – Methodology

Chairperson: D.J. Richards

The first paper of the morning session was "LINAC: An Acoustic Model for the CANDU-PHT System," authored by F.B.P. Tran and A.P. Muzumdar of Ontario Hydro. The LINAC computer code, used to model the acoustic response in a CANDU primary heat transport system, was described. Results were presented that agreed very well with experiments performed in the Stern K12 channel loop.

J.K. Szymanski, also of Ontario Hydro, presented the next paper: "A Hydraulic Model of a Liquid Injection System with Gas Pockets." A model was described that simulated the transient discharge from a system of perforated poison injection nozzles for use in feasibility studies of the Vertical Liquid Injection Shutdown System for Pickering NGS A. Results from the study indicated that an injection system with gas pockets in the lines could theoretically be an effective way of delivering liquid poison into the reactor core.

The last paper, before the morning break, was presented by R. Q-N Zhou of AECL: "Numerical Solution of 30 Stokes Problems." In this presentation pre-conditioned conjugate gradient algorithms for solving 3D Stokes problems by stable piece-wise discontinuous pressure finite elements were presented. Emphasis was placed on the preconditioning schemes and their implementation, and results indicated that these schemes were very effective in reducing the number of pressure iterations at very reasonable computational cost.

A.O. Banas of AECL presented "Numerical Studies of Flow and Heat Transfer Around Fuel-Element Bearing Pads." A general-purpose CFD software system, TASKflow, was used to predict pressure-drop and heat-transfer characteristics for an actual Bruce-type bearing pad in annulus configuration using three-dimensional simulations. It was concluded that intricate geometric effects could be captured and evaluated with this code, and that this work would aid in more accurate modelling of CANDU bearing pads in the ASSERT subchannel code.

The final paper of the session was "Generalized Roe's Numerical Scheme for a Two-Fluid Model," by I. Toumi and P. Raymond of CEA, France. The work presented a six-equation, two-fluid code that is strictly hyperbolic. For the solution of the nonlinear Riemann problem, a generalized Roe's approximate Riemann solver was used. The applicability of the model was demonstrated with a Shock-Tube Problem and the Water Faucet Problem.

Session 3B – Fuel and Fuel Channels

Chairperson: V.J. Langman

Five papers were presented in session 3B, Fuel and Fuel Channels, which spanned a wide range of fuel behaviour modelling, model validation and analysis. In all cases the papers represented the results of work that was closely linked to laboratory or in-reactor experiments or actual fuel performance in power reactors.

In the first paper, presented by Mohammed Bayoumi of Ontario-Hydro, a comparison of analysis predictions, using the CHAN-II (MOD6) code, to the results of an integrated experiment focused of the transient thermal behaviour of fuel sheaths at extremely elevated temperatures (i.e., approximately 1650° C) for 28 element fuel bundle design. Peak sheath temperatures are consistently over-predicted by 100 to 200° C. Peak pressure tube temperature are over-predicted by as much as 250° C.

The next paper, presented by Patrick Reid of Ontario Hydro, dealt with the development of a model to analyze the time-dependent history of the deposition of active Zr95 and Nb95 in a GFP cell. The model was developed as part of the technical program focused on solving the bundle vibration problems in Darlington NGS prior to the installation of 7-vane impellers in the heat transport pumps. The model can be used to indicate which reactor maneuvers (i.e., pumps on/off, power increase), result in increased activity deposition which is associated with enhanced bundle vibration/fretting.

In the third paper, presented by Ken Hallgramsin of AECL Candu Ops, the results of an analysis, using the codes ELESTRES and FEAST, of the stress patterns in the vicinity of the endcap weld upset were discussed. A parametric analysis had been performed in order to delineate which fuel design factors had the most impact on the unwanted formation of cracks at the base of the reentrant notch. Increases in initial fuel density and power ramps were shown to enhance the potential for crack formation.

The fourth paper, presented by Bernard Linet of CEA France, described a comparison between experimental observations on normal operating PWR fuel behaviour and 2D/3D computer code. The results of detailed, multi-dimensional predictions of fuel/sheath thermal and stress distributions, pellet/clad mechanical interactions which could lead to sheath failure, and pellet cracking which could lead to fuel relocation were shown. Comparison to observations of normal operating conditions fuel behaviour indicate that the modelling of 3-D effects is important and required in order to capture mechanisms associated with pellet/clad interaction and fuel relocation. Further work to enhance the 3-D modelling aspects of the code are planned.

The final paper of session 3B, presented by Elias Zariffeh of Chalk River Laboratories, described the results of analysis work also motivated by Darlington N12 incident. The misalignment probability for CANDU fuel bundles was mathematically assessed. The absence of any preferred misalignment between successive bundles was demonstrated. The advantages and applications of a new model for pressure drop at bundle junctions were discussed.

Session 4A – Thermalhydraulics Critical Heat Flux and Subchannel Analysis

Chairperson: A. Tapucu

Paper #1 – SUTRADHAR, S.C., KITELEY, J.C. and CARVER, M.B., "Prediction of Transient Post-Dryout Heat Transfer in Tubes"

This paper examines the validity of existing methods for assessing PDO heat transfer in a tube subjected to slow power transients similar to those that may occur in CANDU reactors. The experimental program consisted of investigating the effects of slow power transients on CHF, PDO, quenching, hysterisis during dryout, rewetting and twho-phase pressure drop. The authors presented data on the surface temperature at the end of the heated length for different power cycles and pointed out that during the power reduction period, the heat flux at which rewetting occurs depends partially on the extent of the prior CHF occurence. Experimental data were also compared to the predictions of the ASSERT-4 .subchannel code and satisfactory results were obtained.

Paper #2 – CARVER, M.B., KITELEY, J.C., JUNOP, S.V. and WASILEWICZ, J.F., "Validation of the ASSERT Subchannel Code for Maple-X10 Reactor Conditions".

Recently, ASSERT has been adapted for use in simulating the MAPLE-X10 reactor. This paper summarized the non-equilibriums model used in the ASSERT code, the equations used to represent this model and the algorithms used to slove the equations. Very few modifications to the ASSERT models were needed to address MAPLE conditions. There modification centered on the manner in which finned fuel rods are treated. The paper also presented the comparison of the ASSERT prediction with experimental data obtained on MAPLE-X10 finned fuel.

Paper #3 – HOTTE, G., JOUHANIQUE, T., "An Investigation into the Accuracy of CHF Modelling in One-Dimensional Two-Phase Flow Analysis".

In this paper, the author showed that the choice of the two-phase pressure drop model has an appreciable impact on the accuracy of the prediction of critical conditions. Comparison of SOPHT predictions with experimental data showed that the representation of the extent of the subcooled boiling region is the most important factor in the accuracy of the predictions. This should be taken in consideration in the calculation of the experimental dryout pressures used in the derivation of CHF models.

Session 4B – Fuel and Fuel Channels

Chairperson: V.S. Krishnan

This session comprised of six papers related to various aspects of fuel and fuel channel modelling.

The first paper presented an analysis of an experiment which simulated water boil-off in a pressure tube with a circumferential temperature gradient. The experiment was simulated using an improved version of the SMARTT computer code. Good agreement between model and experiment was observed.

The next paper summarized results from an out-of-pile 28-element fuel channel experiment and presented a post-test analysis using the fuel-channel code CHAN-II-WL (MOD-28A). The results showed that the Urbanic-Heidrick oxidation correlation predicted the peak hydrogen production rate well. However, at high temperatures, the Prater-Courtright correlation overestimated the hydrogen production rate.

The fourth paper described an experiment to determine the bearing-pad to pressure-tube contact conductance. The finite element program ABAQUS was used to simulate the experiment. It is shown that the heat flow, not the contact conductance, determines the severity of the localized hot spot caused by the contacting bearing pad. An overall heat conductance is suggested to be used in predicting the heat flow into the pressure tube through the contacting bearing pad.

The fifth paper presented a parametric analysis using the multidimensional prototype the two- fluid thermalhydraulic code CATHENA of rupturing fuel sheaths. Altough the agreement between the simulation and the experiment was found to be reasonable, further work was indicated to improve the understanding and modelling rupturing pressure tubes.

The last paper described the application of ANSYS to the modelling of the Pickering NGS fuelling machine and the calculation of thermal stresses during a complete cycle of the refuelling.

Session 4C – Reactor Physics Simulation

Chairperson: B. Rouben and J. Almon

All three papers dealt with simulations of perturbations to the nominal CANDU lattice. They all reflected the state of the art in reactor physics methods applied to problems of current interest in CANDU.

Robinson's and Parkinson's paper, "Improving Flux tilt Control While Adjuster control Rods are Removed from the Pickering NGS A Reactor", addressed the flux peaking caused by the removal of adjuster rods from the Pickering A core, and proposed a modified zone-controller algorithm for this situation. This would maintain individual zone-compartment fills within the operating range when adjusters are withdrawn, and thus preserve spatial (flux tilt) control. This is of significant interest, as maintenance of the control capability is very desirable.

Milgram's paper, "Void Reactivity Predictions for an Infinite Lattice of 37-Element CANDU Fuel", presented Monte Carlo calculations of the void-reactivity effect in the CANDU lattice. The paper points out deficiencies in the modelling capabilities of version MCNP 3B of the Monte Carlo code MCNP. In particular, MCNP 3B does not allow the simultaneous presence of two different scattering representations for the same material (in this case, one for the relatively cool D_2O moderator, and another for the hot D_2O coolant). This deficiency is apparently resolved in version MCNP4. Monte Carlo calculations are quickly gaining in importance as methods for doing reactor-physics (especially lattice) simulations.

The paper presented by Smith et al, "Advances in the Physics Modelling of CANDU Liquid Injection Shutdown Systems", describes a system of computer codes to model the liquid-injection shutdown system (SDS2) in CANDU. The operation of this system leads to a complicated three-dimensional picture of gadolinium poison concentration in the calandria. Many different codes are needed to model the thermalhydraulics of the injection and the neutronic effect of the poison propagation. The simulation system which was put in place is a great held in automating interaction between the different codes and in minimizing the effort in simulating SDS2 operation.

Session 5A – Safety Analysis

Chairperson: Simon Pang

Four papers were presented in this session.

1. Simulation Problems of Advanced LWR by S.M. Modno.
2. COPWATZ: An improved thermohydraulic code for LOPWA Analysis for a SOS-10 Reactor by J.T. Rogers.
3. ROSA-IV LSTF 5% cold leg break Analysis Using RECAPS/Mod 2 code by F. de Pasquale.
4. Analysis of Reverse Flow Consequence During Gentilly-2 Channel Refuelling.

The first paper presented some interesting and innovative passive design fealines from AP 600 and simplified BWR. Because of the relatively low pressure and small driving force, the characteristics of natural circulation or gravity driven transfer processes have significant impact on performance of the safety features. These passive features offer quite a challenge to model the phenomena accurately.

The second and third papers also dealt with natural circulation phenomena. The second paper presented evidence that confirmed the inherent safety of the Slowpike Energy Systems. The third paper provided an insight of the complex 2-phase natural circulation behaviour in the ROSA IV LSTF.

The fourth paper was different from the others. It dealt with impact forces from a fuel storing resulting from reverse flow in a fuel channel following a LOCA. Good comparison with experimental results was achieved by a relatively simple model.

Session 5B – Reactor Physics Methods

Chairperson: Guy Marleau

Des cinq communications prévues à cette session, seulement quatre ont été présentées, l'une d'entre elles par un chercheur à l'électricité de France (EdF) et les trois autres par des chercheurs à l'école Polytechnique de Montréal.

La première présentation décrit une méthode de modélisation pouvant être utilisée pour simuler les effets de spectre à l'interface coeur-réflecteur lors de calculs de diffusion neutronique dans un réacteur à eau pressurisée (PWR). Cette méthode est basée sur l'évaluation d'une matrice de réponse qui relie les courants et les flux multigroupes à l'interface coeur-réflecteur. Ce calcul est basé sur une analyse en géométrie unidimensionnelle de la réponse du réacteur à différentes perturbations des paramètres physiques du coeur, suivie d'une extrapolation aux géométries bidimensionnelles. Des résultats préliminaires obtenus en appliquant cette méthode aux réacteurs PWR sont finalement discutés.

La seconde présentation introduit une technique de résolution de l'équation de diffusion des neutrons qui est basée sur la méthode des éléments finis utilisant une fonctionnelle mixte-duale. Les avantages de cette méthode, incluant sa compatibilité avec la méthode ADI ainsi que sa convergence accélérée vers la solution exacte, sont présentés. De plus, un algorithme de vectorisation de la ADI est décrit. L'efficacité de ces techniques est ensuite démontrée pour différents modèles de réacteurs.

La troisième communication porte sur des calculs en transport neutronique tenant compte des conditions de réflections spéculaires aux limites d'une cellule CANDU. Elle décrit l'utilisation d'une méthode de calcul des probabilités de collisions basée sur une quadrature numérique choisie de façon à ce que les lignes d'intégration soient cycliques. Des comparaisons avec la méthode standard de traçage des lignes d'intégration, qui ne permet que l'utilisation de conditions de réflection isotropes aux limites d'une cellule, sont aussi présentées.

Finalement, la dernière communication discute d'une modification à la loi de Fick qui prend en compte le courant dû à la dérive des neutrons dans un réacteur non symétrique. Cette présentation est divisée en deux parties. Premièrement, une dérivation du terme de dérive en théorie du transport, basée sur l'application de la méthode d'homogénéisation de Benoist à des cellules non symétriques, est présentée. Ensuite, les équations modifiées de la diffusion neutronique sont analysées. Finalement, les résultats obtenus pour un calcul de diffusion dans le réacteur CANDU avec contrôleurs liquides dans des positions asymétriques sont discutés.

Session 5C – Thermalhydraulics Experimental Analysis and Validation

Chairperson: Frank Stern

Dr. Muzumdar's paper explained the changes made to the WHAM Acoustic Model and how these had resulted in greatly improved predictions of experimental results, over a broad range of conditions pertaining to the Darlington/-Bruce B fuel damage problems. The audience reaction to this paper was very positive and questions had to be limited to the time available for discussion.

Mr. Tye presented a paper on an experimental program addressing the Counter-Current Flooding Limit in Vertical Tubes. The results were compared with existing correlations. Questions addressed the experimental methodology and interpretation of results.

Dr. Amrouni gave a paper on a Thermosyphoning Model and Experimental Verification. This covered work performed to develop and analytical understanding of the phenomena observed during thermosyphoning in a loop with CANDU geometry. The independent behaviour of flow in individual steam generator tubes is the major finding. The paper was followed by a lively discussion which kept the audience in the room for more than 15 minutes into the coffee break.

A paper covering the Validation of CATHENA against Feeder Refill Experiments was given by Dr. Popov. CATHENA is a full two-phase code containing an extensive heat transfer package and models for components such as valves and pumps. It continues to be validated for a wide variety of conditions; in this case these applied to gravity driven feeder refill. The overall trends were well represented by the code.

A paper on Flashing Two-Phase Flow in Blowdown through a Nozzle was presented by Dr. Chan. This addressed the reaction forces resulting from high pressure, high temperature blowdown. These were measured for a variety of conditions in an experimental facility designed to yield accurate measurements of force magnitude and direction. Questions addressed the experimental methodology and interpretation of results.

Session 6A – Safety Analysis

Chairperson: S.M. Modro

The first paper was presented by Ian Shepherd of the Commission of the European Communities Joint Research Centre in Ispra, Italy. His paper entitled, "ESTER: A New Approach in modelling Severe Accidents" dealt with the design philosophy of an European tool for severe accident analyses. ESTER is a tool that makes use of existing codes. This work not only showed very good innovative and efficient utilization of existing research and development results, but also proved that an effective collaboration between several countries can be achieved and lead to optimal use of resources.

The second paper entitled "Simulation of Large Break Loss-of-Coolant Accident with TUF and SMOKIN Computer Codes" was presented by Dr. Z. Farouqui of Ontario Hydro. This paper addressed safety analyses through the use of two separate codes, one a thermal-hydraulic and the other neutronic, that can be linked interactively or self-initiating, where the former method gives a rigorous three-dimensional neutronic capability.

The third paper entitled "SB-LOCA Analysis of Westinghouse Two-Loop PWR Using the RELAP3/MOD2.5" was presented by F. de Pasquale of the Paul Shcerrer Institute, Switzerland. Four selected calculations were presented. The study showed that all cases will result in plant response within licensing limits. It also showed the severity of the accident is not proportional to the break size.

D.J. Oh of KAERI, Korea, presented the fourth paper of this Session entitled, "Predictions of Fuel Channel Behaviour for Large LOCA in CANDU Reactors". This paper described the CATHENA model used for simulation and results of a 20% reactor inlet header break in the CANDU6. Comparisons to HOTSPOT calculations were also shown.

The last paper of the Session was presented by M.Y. Ohn of KAERI, Korea. This paper entitled, "CANDU6 Steam Line Break Analysis with CATHENA", showed an analysis of two cases with different assumptions for the efficiency of the steam separators. The analysis indicated the break discharge is very sensitive to the steam separator efficiency.

It was a very good Session with a very active audience and intensive discussions.

Session 6B – Reactor Control and Operation

Chairperson: A. Tessedou

Paper #1 – GROSS, K.C., et al., "Iterative Graphics Driven Simulator for EBR-II," ANL, USA.

The development of a full fidelity, interactive, real-time reactor plant simulator for Liquid Metal Reactors was presented. The simulator itself was applied to the Experimental Breeder Reactor-II (EBR-II at ANL). The principal software engine is based on the SASSYS code developed at ANL. This code, written in FORTRAN, was originally running on single-processor mainframe computers. In order to implement the simulator presented in this conference, a modified version of SASSYS called LSAS (Little SAS) was used. The principal goal being the use of distributed parallel computing systems throught of system called P4 that allows large FORTRAN codes to be parallelized across conventional low cost Unix Workstations. The network used for running the simulator is composed of 30 Sparc-II workstations. In order to improve the message-passing time, modifications to the communication protocol were required.

The operator interface consisted of more than twenty very high resolution graphical displays. The graphical interface software was developed under the X Windows platform. The interface images presented at the conference were of a very impresive quality.

Paper #2 – PHILLIPS, B.S. and STAMBOLICH, J.Y., "Development of a Computerized Shutdown Heat Sink Manual," Ontario Hydro.

In this paper the development of a computerized Shutdown Heat Sink Manual was presented. The principal objectives being the preparation of a user-friendly manual that can be used by the operations staff to identify and develop the appropriate shutdown strategies. The software presented was entirely written by using the well known EXCEL package. The results presented were obtained by running Excel on standard 386/486 systems. Even though some of the thermal calculations seemed to be greatly simplified, it was very interesting and surprising to see the high quality of the graphics interface presented.

Paper #3 – McGEE, G.R. and CICHOWLAS, W.M., "Thermal Performance Monitoring at Pickering NGS Using Thermac", AECL Research and Ontario Hydro

Some of the strategies that have been implemented at Pickering Nuclear Generating Station (NGS) to monitor the thermal performance of the turbine cycle were described. The software tool used for this purpose is a commercial programme called THERMAC. One of the major advantages in using THERMAC is the fact that it runs under PC envirionments providing a quite good graphic user interface. Since THERMAC handles several types of calculations, the simulation of different operating modes is possible; those presented during the conference were: predictive performance, component performance, and data conditioning. The appropriate use of each of these modes may help to diagnose and eventually locate thermal losses, investigate possible configuration changes required and follow the deterioration of systems performance with time.

Paper #4 – GARLAND, Wm.J. et al., "Towards a Generic User Support System (GUS)," McMaster University

During the presentation the audience was invited to hear and follow a fascinating talk where the main question was: How operators of Nuclear Power Stations have to be supplied with appropriate tools to perform at optimum capacity and lesser risks? Is it possible to differentiate high level time-consuming engineering tasks with fast reactions required by the operator, and put these tasks into a "universal" user-friendly interface? All of these questions have been coherently presented and answered by someone that not only knows the subject but also knows how complex things can be understood by everyone.

Paper #5 – FIRLA, A.P., "Statistical Analysis of Spread-Check Limits with Median-Type-Estimators,", Ontario Hydro.

This paper presented statistical mathematical tools for determining a more objective choice of "Spread Check Limits (SCHL)." Presently, SCHLs are determined from data gathered from operational experience. According to Dr. Firla, this is not a uniform and rational approach. Due to the random nature of errors in the measurement loops used for the trip, a probabilistic criterion for the SCHL selection must be developed. The derived equations can be used for any type of distributions, and can easily be implemented on 386/486 systems. During his presentation, Dr. Firla was able to explain the complicated subject and the concepts of probability theory with great clarity.

Call for Papers

CNS Annual Conference

5-8 June 1994, Montreal

Send summaries (original and three copies) of 750 to 1200 words to:

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DEADLINE IS 30 NOVEMBER 1993

Canadian Nuclear Society Financial Statements • December 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 December 31, 1992 and the statements of operations and surplus and education fund for the eleven months 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 December 31, 1992 and the results of its operations for the eleven months then ended in accordance with generally accepted accounting principles.

Toronto, Ontario
May 21, 1993

Doane Raymond
Chartered Accountants

Balance Sheet

	Dec. 31, 1992	Jan. 31, 1992
ASSETS		
CURRENT		
Cash	$148,443	$ 88,998
Receivables	52,424	20,922
Prepaids	691	—
Short term deposits (market value $92,782; 1991 – $133,384)	93,403	133,384
Conference advance	6,000	—
	300,961	243,304
CNS share of education fund assets (Note 2)	12,000	12,000
	$312,961	$255,304
LIABILITIES		
CURRENT		
Payables and accruals	$ 48,728	$ 2,475
Payable to CNA	56,553	62,369
Membership fees and contributions received in advance	11,892	19,782
	117,173	84,626
EQUITY		
Accumulated surplus	183,7881	158,678
Education fund (Note 2)	12,000	12,000
	195,788	170,678
	$312,961	$255,304

See accompanying notes to the financial statements.

Statement of Operations & Surplus

	11 months ended Dec. 31 1992	12 months ended Jan. 31 1992
INCOME		
Membership fees	$ 33,914	$ 33,995
Publications	4,269	5,638
Interest	7,038	14,985
Other	6,870	—
Loss on sale of investment	(10,712)	—
	41,379	54,618
SOCIETY PROJECTS		
Excess of income over expenditures		
Annual conference	15,188	31,649
Nuclear simulation symposium	4,863	10,306
CANDU maintenance conference	61,414	—
CANDU fuel conference	7,021	—
Regional overpower trips course	4,225	—
CANDU chemistry seminar	—	2,143
Containment design & operation conference	—	258
Steam generator & heat exchanger conference	—	568
Neutron radiography conference	—	5,908
Fusion seminar	—	1,211
	92,711	52,043
	134,090	106,661
EXPENSES		
Office overhead charge from CNA	27,500	30,000
Office services	20,957	27,895
Canadian Nuclear Society *Bulletin*	26,344	18,291
Branch activities	6,720	(501)
Membership committee	14,780	8,820
Program committee and technical divisions	1,058	1,697
Stationery and printing	4,990	4,181
Council activities and promotion	3,276	3,161
Students' conference	1,500	3,799
Innovative Achievement Awards	1,168	5,711
International Nuclear Societies	687	—
	108,980	103,054
Excess of income over expenses	25,110	3,607
Surplus, beginning of period	158,678	155,071
Surplus, end of period	$183,788	$158,678

Statement of Education Fund

	11 months ended Dec. 31 1992	12 months ended Jan. 31 1992
Surplus, beginning of period	$ 12,000	$ 12,000
Surplus, end of period	$ 12,000	$ 12,000

See accompanying notes to the financial statements.

Notes to the Financial Statements • December 31, 1992

1. SUMMARY OF 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 adjusted for amortization of premiums or discounts.
   (c) **Change in year end**
   The Society changed its year end to December 31 from January 31 effective December 31, 1992. Accordingly, the current year financial statements cover an eleven-month period.

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:

		Dec. 31 1992	Jan. 31 1992
Principal contributions:	CNA	$ 28,000	$ 28,000
	CNS	12,000	12,000
		40,000	40,000
Accum. interest available to CNS local branches		15,199	11,725
		$ 55,199	$ 51,725

From the President

Ed. Note: *The following is extracted from comments made by CNS President Paul Fehrenbach at an "Appreciation Dinner" held October 4 during the INC '93 conference.*

As you know, the Canadian Nuclear Society is a society of individuals who are engaged in various capacities throughout the Canadian nuclear industry.

We are currently a society of 750 members – and still growing. Our industry is national in scope and our membership reflects this with members from Saskatchewan to New Brunswick. We are also beginning to acquire an international flavour with members in Romania and other parts of the world.

The Society relies on the volunteer effort of those, such as you present, who plan and organize CNS events on the local, national and international scene. There are no paid officers in the CNS.

While paying tribute to individuals we should also acknowledge the support of our employers – both in supporting those involved in organizing activities and by sending participants to CNS sponsored technical meetings and conferences.

This should not be regarded as philanthropy. As [past-president] Bill Midvidy has pointed out on numerous occasions, the CNS serves a valuable role providing a Canadian forum for presentation of the technical achievements of our industry and for the very important technical exchange which occurs at such conferences. This is a valuable component of professional development for individuals. International meetings, such as the International Conference on Simulation Methods and the International Conference on Expanded and Rolled Joint Technology held recently, and, of course INC '93, also provide opportunities for international exchange.

Let me now say a few words about the current directions and priorities for the CNS as I and the current Council see them.

Beginning with membership – I mentioned that our membership is approximately 750 and growing. We have attracted over 100 new members in each of the past few years (thanks to Membership chairmen Jerry Cuttler and Hong Huynh), but we have not grown by that number since a significant fraction of existing members are not renewing their membership. We need to discover why not and better understand the expectations of existing and potential new members.

One need we have identified is for programs to address the interests of those in the operations side of our nuclear utilities. We plan to form an Operations Division later this year and I am pleased to report that Ken Talbot has agreed to take on the chairmanship of this new enterprise.

Another priority area is Branch activities. I am pleased to report that all ten branches are again active and several have impressive programs. Local branches are the primary contact between the Society and individual members and the current Council will provide all the encouragement and support that it can.

This leads to a third priority – to raise the public profile of the Society as a credible technical voice on behalf of nuclear technology in Canada. Branches are being encouraged to be more proactive in their communities in sponsoring events of general public interest and becoming more closely involved in local educational projects. The CNS has taken on sponsorship of an Outreach Program begun by the CNA and being developed by Stan Hatcher and Roxanne Summers to meet with, listen to, and understand public concerns.

Finally, let me note again the very important role of the Society in organizing conferences. This is the primary responsibility of the four (soon to be five) technical divisions of the CNS. Council has always placed a strong emphasis on such meetings and, collectively through the hard work of many, we have been successful. Those involved in the organization of INC '93 deserve special credit for the success of this world-class event.

In listing CNS achievements over this past year I would be remiss if I did not note the continued high quality of the CNS *Bulletin*. The *Bulletin* is our main channel of communication with our members and, as such, is a very important component of our activities.

The CNS is now in its fourteenth year. We have come a long way in a relatively short time; we have matured as a society and are entitled to the confidence we have developed as an important contributor to the success of the Canadian nuclear industry. We have a continuing strong role to play in ensuring that nuclear energy is an important component in providing the energy needed for the economic well-being of Canada and its citizens.

Deadline

The deadline for the next issue of the
CNS *Bulletin*, Vol. 14, No. 4,
is December 17 for publication in early January 1994.

Four CNS Fellowships Awarded

At a special dinner held October 3, 1993, during the INC '93 conference in Toronto, four long-time members of the Canadian Nuclear Society were named as **Fellows** of the Society in recognition of their contributions over the years. Honoured were John Foster, Terry Rummery, Ken Talbot and Alan Wyatt.

Each Fellow of the Canadian Nuclear Society is elected by the Society membership as a whole, and belongs to a special membership category denoting outstanding merit. The criteria for admission include "major and sustained contributions to the sciences and/or professions that relate to the advancement of nuclear technology in Canada." Demonstrated maturity of judgement and breadth of experience, as well as outstanding technical capability and service to the Society are also requirements. In the tradition of honorary membership categories of learned societies, CNS Fellows are entitled to add the letters "F.C.N.S." to letters denoting degrees and professional certifications following their names.

Following are the citations read out by Awards Chairman John Hewitt for each of the recipients.

Citations

John S. Foster, Honorary Chairman, World Energy Conference, *"For his pioneering roles as engineer and technical leader in bringing about the* first *CANDU nuclear energy plant, for his direction of AECL Power Projects during the design evolution and implementation of the succession of CANDUs that includes Pickering A, Bruce A and CANDU 6 plants, and for his wide-ranging executive and other leadership contributions to Canadian and world nuclear energy development, including his valued encouragement and counsel in founding of the CNS."*

Terrance E. Rummery, President, AECL Research Company, *"For his outstanding scientific and technical contributions in predicting optimal coolant operating conditions in CANDU reactors and in the early direction of the national program to develop the technology for the safe disposal of used fuel from Canada's power reactors, and for his major and sustained contributions to the sciences and professions in Canada as head of Canada's second largest research and development organization and promoter of professional development among colleagues."*

Kenneth H. Talbot, Director, Bruce 'A' Nuclear Generating Station, Ontario Hydro, *"For his exemplary contributions in the technical supervision and management of the many facets of the operation and maintenance of Ontario Hydro's nuclear-electric generating stations, for pioneering work in the development and execution of the re-tubing procedures for CANDU reactors, and for his untiring and enthusiastic support of technical and professional advances in the industry, in part through his key roles in the affairs of the Canadian Nuclear Society, including his CNS presidency in 1988-89."*

Alan Wyatt, Consulting Engineer, Former Vice-President and General Manager, CANATOM (Ontario), *"For his diverse technical and managerial contributions within nuclear power industry, for his many scholarly writing and publishing activities reaching scientific, technical, regulatory and public audiences, and for his patient and persistent nurturing of a greater understanding of the issues of the nuclear debate, and his prolific and effective interpretation of this understanding to the public."*

Background

The following background notes on each of the new CNS Fellows were provided by the CNS Awards Committee.

John S. Foster, F.C.N.S. John Foster is a native of Halifax, Nova Scotia. He attended Dalhousie University and the Technical University of Nova Scotia, graduating with a Bachelor of Engineering degree in Mechanical Engineering in 1943.

Following graduation, he served in the Royal Canadian Navy until the end of the war, and then returned to Nova Scotia to obtain his B.Eng. degree in Electrical Engineering in 1946. He won the Governor General's Medal for graduating at the top of his class.

After graduating, he joined Montreal Engineering, where he worked on thermal power plant engineering, until he moved to Chalk River in 1953, to help with the rehabilitation of the NRX reactor.

In 1954, he joined the Nuclear Power Group, which produced a feasibility study for a heavy-water moderated reactor for power generation. When the decision was taken to proceed with the design and construction of the 20 MWe NPD power reactor demonstration plant. John Foster was appointed to head the design team at Canadian General Electric.

In 1958, John was appointed Deputy Manager of the new AECL Nuclear Power Division, which was formed to begin the design of a 200 MWe prototype full-scale nuclear generating station, to be built at Douglas Point. He became General Manager later that same year. The Douglas Point plant was subsequently used as the model for the two-unit plant at Rajasthan, India.

The Nuclear Power Division was later renamed AECL Power Projects, and John Foster was appointed Vice-President in 1966. He led the Power Projects organization through a challenging period, during the design of Pickering A, Bruce A, and the CANDU 6 plants. He also managed the engineering and construction of the Bruce Heavy Water production facility, and the first 1000 MW phase of the Nelson River Transmission Line in Manitoba.

John Foster served as President of AECL from 1974 to 1977. From 1978 to 1984, he was Vice-President of the Monenco group of companies and a Director of Monenco Limited, the holding company.

Throughout his career, and particularly since 1984, John has served the industry in many other capacities. Only a few can be mentioned here. John served as Chairman of the Canadian Nuclear Association in the late 1970s. John was a Charter Member of the World Energy Conference, subsequently renamed the World Energy Council, and served as

President of WEC from 1989 to 1992. He is currently a member of Ontario Hydro's Technical Advisory Committee on Nuclear Safety.

John Foster is a charter member of the Canadian Nuclear Society, and as a member of the organizing committee gave valued encouragement and counsel in the founding of the CNS. It was clearly this kind of support, whatever the undertaking, that earned for John the respect of all who have had the privilege of working with him.

Dr. Terrance E. Rummery, F.C.N.S. Terrance Rummery graduated in 1961 from Queen's University with a B.Sc. (Hons) in Engineering Chemistry. In 1966 he received the Ph.D. in Physical Chemistry, also at Queen's. He completed his formal scientific education as a National Research Council post-doctoral fellow working with the renowned crystallographer Dame Professor Kathleen Lonsdale at University College, London, England.

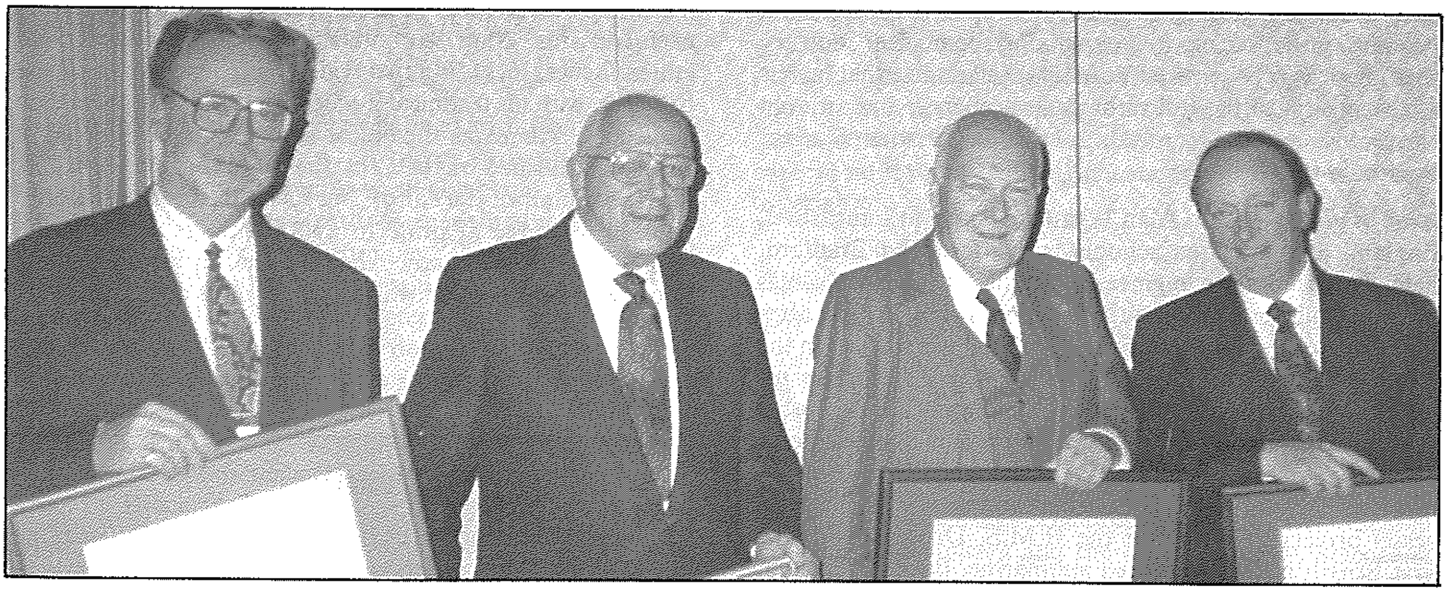
Early in his outstanding career as a researcher, Terry investigated the chemical and physical properties of glass at the Ontario Research Foundation and studied the coking process at the American laboratories of Airco Speer Carbon and Graphite. In 1971 he joined the Research Chemistry Branch of Atomic Energy of Canada Limited's Whiteshell Laboratories where he produced the chemical data to predict optimum operating conditions in the primary coolant of CANDU nuclear power reactors. He took over leadership of the branch in 1976.

In 1979 Dr. Rummery was selected as the first head of the national program to develop the technology for the safe disposal of used fuel from Canada's nuclear power reactors. His mandate included formulating scientific and engineering programs and establishing a multidisciplinary staff. Research and development contracts to universities and private industry throughout Canada, and a wide-ranging commitment to exchange information with the international scientific community, were important features of the program. Capital projects included the Underground Research Laboratory, unique in the world, for the *in situ* study of geological, hydrogeological and chemical factors important for the eventual construction of a full-scale disposal facility. Terry's competent direction of the complex nuclear fuel waste management program was preparatory to the executive responsibilities to come.

In 1984/85, Terry attended Canada's National Defence College in Kingston, Ontario. Subsequently, he moved into a new career as team leader in CANDU power reactor marketing activities in Yugoslavia and the Netherlands. Following a series of special assignments at AECL's Corporate Office beginning in 1988, Terry was appointed as acting President of the AECL Research Company in July 1989. He was confirmed President of AECL Research in 1990. For several months during 1993 he also served as acting President and CEO of AECL.

Terry Rummery has clearly made major and sustained contributions to the sciences and to the professions in the advancement of nuclear technology in Canada. His distinguished career which embraces research and development, management of scientific programs, exploitation and marketing of nuclear products and services, and executive direction within AECL, Terry Rummery has made an outstanding contribution to Canadian nuclear knowledge. Canada's world leadership in the field of nuclear waste management is testimony to his inspiring leadership during the development of the Canadian research program.

In addition to his direct influence upon the nuclear program he has pursued parallel interests, including public awareness of nuclear energy, science education, and the fostering of professional participation in the activities of the CNS. He supports academic initiatives to enhance higher education in engineering and the sciences and accordingly has been a member of the Queen's University Advisory Council of Engineering. He is also Chairman of the INC '93 (International Nuclear Conference) Advisory and Resource Committee. Dr. Rummery is a Fellow of the Chemical Institute of Canada and a Member of the Association of Professional Engineers of Ontario. He is, of course, a charter member of the Canadian Nuclear Society.



The new CNS Fellows for 1993 pose for the Bulletin *following the presentation at a special dinner during INC '93 in Toronto, 3 October 1993. L-R: Terry Rummery, John Foster, Alan Wyatt, Ken Talbot*

Kenneth H. Talbot, F.C.N.S. Kenneth Talbot was born and educated in the area of Rugby, England. He graduated in mechanical engineering from the Rugby College of Engineering Technology. After receiving a post graduate diploma in steam turbine engineering from the same institution, he worked for English Electric as a research and development engineer before coming to Canada to join Ontario Hydro at their Pickering Nuclear Generating Station in 1970. His career has been a steady progression from assistant technical engineer to technical supervisor, technical superintendent, commissioning manager, and then Manager of the rehabilitation operations for Units 1 and 2 at the Pickering 'A' NSG. Following a two year period as manager Corporate Planning, he was appointed to his present position as Station Manager (now Director) of Bruce 'A' nuclear generating station.

Ken Talbot is highly regarded in the nuclear community as an outstanding technical manager and supervisor; he is highly organized ("the most organized person I know" said one colleague), motivated, and an inspiring team leader. In the Pickering re-tubing operation, the first of this magnitude, Ken led his team in pioneering work in the development and execution of the re-tubing procedures. These procedures proved so successful that they have become a standard for all such operations in the future. Since arriving at Bruce 'A', Ken has been highly effective in introducing and developing Ontario Hydro's "total quality" program in station management, including the introduction of employee representation on the station's Management Council. His management skills yield results; his management team was commended as having achieved "a breakthrough in performance improvement" following a recent detailed peer evaluation.

Ken Talbot is a charter member of the Canadian Nuclear Society and has played major roles in the development of the Society, holding many key chairs and offices on the Council before becoming President for 1988-89. Recently he has served as the Society's Chair for International Liaison Committee and Vice Chairman of the corresponding committee of the American Nuclear Society. His enthusiasm and energy have been employed not only in managing the affairs of the Society but also as an effective spokesman promoting the Society and explaining the nuclear industry to audiences. Those who know Ken well realize that he has a clear vision of the future of nuclear energy, and an even clearer vision of the important role of the Canadian Nuclear Society in this vision.

Alan Wyatt, F.C.N.S. Alan Wyatt was born in Lancashire, England and attended schools in Watford and Bradford, before proceeding to engineering studies at the Naval Engineering Colleges of Plymouth and Greenwich. In 1957 after his first twelve-year "first career" as Engineer Officer in the Royal Navy, Alan came to Canada where he began his multifaceted association with the Canadian nuclear industry as thermal project engineer for the embryonic Douglas Point generating station. Before settling permanently in Canada, however, he returned to Britain for two years as the pressure vessel project manager for the H.M.S. Dreadnought, the first British nuclear-powered submarine. Back in Canada, between 1962 and 1983, Mr. Wyatt held a series of academic, senior engineering and upper management posts with H.G. Acres, AECL Power Projects, Niagara College of Applied Arts and Technology (where for a time he was Dean of Technology), CANATOM in both Montreal and in Toronto where he was CANATOM Vice-President (Ontario), and MONENCO (Montreal Engineering Company). Since 1983, Alan has been a consulting engineer in independent practice, an author and a publisher based in Toronto. This summer Alan and his wife Rachel, apparently having had enough Toronto winters, moved to Victoria, B.C.

This chronological framework as stated is impressive in itself. But on looking closer we find an intricate counterpoint of several themes that distinguish Alan Wyatt's already meritorious career profile. First, there is Alan Wyatt the Engineer – the person to be entrusted with a technical task of monumental human-safety, economic, or legal importance. The fact that Alan has been called upon frequently to perform and report on technical and economic audits in the international sphere as a consultant in the last ten years bears witness to an ability for insight and analysis that was highly crafted in earlier years. Second, there is Alan Wyatt the Project Study Director leading study teams in such still-topical studies as: "The Substitution Potential of Electricity for Oil," the "Economics of a Solar Heating Plant," and the "State of the Art of Flue Gas De-sulphurization."

And then there is the analyst, author, expert witness and debater focusing on the social and ethical issues surrounding nuclear power. In forming and presiding over various CNA committees established for the purpose, Alan has been a pioneer and an inspiration to others in developing the ground work on how to deal with these issues. He has been commended by professionals (I should say *other* professionals) for his credibility and communication skills at more than 100 appearances on behalf of the industry before numerous inquiries and commissions (such as the Porter Commission on Electric Power in Ontario and the interfaith hearings sponsored by five religious groups), on radio and television panels and debates. He is equally at home with politicians, scientists, engineers, and at service clubs; perhaps his earning a graduate degree in political science in mid-career, a remarkable achievement in itself, turned out to be extremely useful in this. Alan has published widely on social and ethical issues, including two widely accepted books. These together, with his technical publications, number more than 80 articles. Alan was the editor of the Nuclear Journal of Canada published by the CNS; the journal had a short life, due to no fault of the editor, but its high editorial standard made it a source of pride to CNS members and a useful reference source to many. Alan is a charter member of the Society and has been a loyal supporter of its objectives.

Deadline

The deadline for the next issue of the CNS *Bulletin*, Vol. 14, No. 4, is December 17 for publication in early January 1994.

Branch Activities

Ed Note: The following article is based largely on a report prepared by Branch Chairman Jerry Cuttler for the CNS Council, supplemented by input from the Branches.

General

All the branches are operational and beginning their programs for the 1993-94 season. Hydro restructuring has affected the operation of some branches. A greater focus on operations-related activities should help increase interest and membership in the CNS in those branches closely associated with nuclear generating stations. The transfer of Ontario Hydro design staff to the stations should also help to strengthen these branches. These "interesting times" offer challenges to CNS branches to engage those who believe in the future of the applications of nuclear technology for the betterment of humanity.

Bruce

Karel Mika is branch chairperson, and Glenn Sutton is secretary. The other positions will be filled in the fall. The OH restructuring has taken up much of the branch's attention. During the summer, there was participation in activities organized by the Action BNPD Coalition in support of Bruce NGS A, the heavy water plant and the Bruce Energy Centre. The CNS was publicized and membership in the CNS was promoted. A program is being planned that will cover topics such as: hydrogen and nuclear power (E. Jelinski), cleanliness of the water around Bruce (MOE), credibility gap (R. Sommers), etc.

Central Lake Ontario

A council meeting was held at Darlington on September 20 in conjunction with a branch activity (talk by J. Nathwani entitled "Perception and management of risk"). Dan Meraw is branch chairperson. He is looking for more people to get involved in running the Branch. He is planning to have at least two events; the dates and topics have not yet been chosen.

Chalk River

The branch executive has been defined with Bob Andrews as the chairperson. The last talk of the Spring 1993 season was given on June 1 by Françoise Guenette, AECL Vice-President for Corporate Relations speaking on "Public affairs, Challenges, and Opportunities." Two book prizes for Grade 12 and 13 mathematics were presented at Deep River's Mackenzie High School by Peter Laughton, our branch vice-chairman. The branch also donated a bursary to the Deep River Science Academy to subsidize a student at its 1993 session.

The program for 1993-94 is taking shape. Eight talks are planned. The session kicks off on October 26 with a presentation by Bruce Howe, President of AECL. Among other topics to be covered are: Advanced CANDU; the Sudbury Neutrino Observatory; the role of natural analogues in nuclear waste management; biotechnology and radiation biology. Dr. Alvin Weinberg is scheduled for late April in 1994.

Golden Horseshoe

On August 11 Kenneth Kozier of Whiteshell Laboratories gave a historical perspective on "WR-1: Canada's Organic-Cooled Reactor Prototype." On September 28 two visiting Japanese engineers made presentations: S. Sugiyama from Nuclear Power Engineering Corporation (NUPEC) spoke about "Current Research Activities at NUPEC in Support of Nuclear Power Plant Safety," and K. Hori from Mitsubishi Heavy Industries discussed "Advanced X-Ray and Gamma-Ray Techniques for the Measurement of Void Fraction in Subchannels and Rod Bundles." Future seminars, of both a technical and a public-interest nature, are planned for approximately once a month.

The new 1993-94 Executive is: Co-chairmen, Jeremy Whitlock and Glenn Harvel; Secretary, Charles Baetsen; Member-at-large, Bill Garland.

Manitoba

Current branch chairman Chuck Vandergraaf reports that the inaugural meeting of the Manitoba Branch is being held October 21 at the Whiteshell Laboratories at which time the new executive will be chosen.

The branch plans meetings about every six weeks following the format developed over the first half of 1993, which involves lunch talks at WL, and evening presentations in Pinawa.

At the inaugural meeting plans to increase the profile of the CNS in Manitoba will be presented. These include cooperation with other scientific groups and the Whiteshell branch of the Deep River Academy.

New Brunswick

Paul Thompson continues as chairman; Ryan Jennings has joined as a Member-at-large. A meeting was held in September, and the program for the next three months was defined. In the third week of October, the topic is "a systematic approach to plant system training"; in November, the topic is "progress at Cernavoda"; and in December, the topic is "SLAR for Lepreau." The branch organizes three months at a time, but a long list of potential speakers was prepared. April is the annual Lepreau shutdown, so there will be no CNS meeting in that month. The annual dinner meeting will be in May.

Ottawa

Jeff Lafortune will lead the branch for 1993-94. Four or five meetings are planned for the year. The first meeting, October 28, will be on the Ernst & Young study on the return on the return on Canada's investment in nuclear technology. In December, Colin Allan will give a talk on AECL's high level waste management program and the upcoming environmental review hearings. The other topics are: NRC research on medical dosimetry and the ISTC (Industry, Science & Technology Council) report on the Canadian Science Policy. The branch is seeking to improve participation and utilize the expertise. It will also expand its audience and emphasize its educational role by developing more solid ties with the academic community, schools (e.g. scholarship fund, science fair) and with other local professional organizations, such as APEO and CRPA.

Quebec

The branch executive is defined and includes one from Gentilly-2. Norman Gilbert is the chairperson in Montreal, and Marc St-Laurent is the vice-chairperson (at G-2). Others from G-2 will be added. The program is still being defined. A meeting is being planned for November 24 to hear a presentation by Dr. Marvin Goldman (President-elect of the Health Physics Society) entitled, "Radiation Lessons from Russia." (This could be held in conjunction with a CNS executive meeting.) Other topics planned: advanced research in Canada, SLOWPOKE/RUTA, MAPLE-X, fusion, a video presentation, presentation by Prof. D. Rozon, visit to the tokamak at Varennes.

Saskatchewan

Dave Malcolm continues as chairperson. A meeting was held October 4 to plan the program for 1993-94 and discuss other business.

Toronto

The branch executive was defined in the executive meeting of June 24, but they are looking for additional members. Greg Evans is the chairperson. Seven meetings are planned for 1993-94, starting with a presentation by J. Fox on September 28 entitled "Ontario Hydro's new focus, energy services and environment." Future topics include ethical issues of radiation exposure, siting task force for low-level waste management, presentations by A. Dickenson of AMPCO, Dixie Lee Ray, Sean Conway, and a talk on DNA testing for criminal cases. The student chapter is actively planning the student conference to be held March 18-20.

News of Members

Hortons Retire

The Horton brothers, Sam and Elgin, both pioneer members of Ontario Hydro's nuclear program, retired together August 31.

Both were part of the original crew for NPD, the small demonstration plant that began Canada's nuclear power program. They joined the NPD group in 1960, two years before the plant started up and were among the first half dozen supervisors authorized by the Atomic Energy Control Board.

Sam was an early superintendent of NPD, then of Douglas Point and went on to be Project Manager of the Bruce Nuclear Development. In the 1970's he took on broader responsibilities as Director of Generation Projects, then Vice-President of Supply and Services, and later V.P. Design and Construction. In 1984 he became Executive Vice-President, Engineering Services and subsequently E.V.P. of Human Resources. Two years ago he moved to Senior V.P. Aboriginal and Northern Affairs.

Elgin was also a manager of NPD, then of Pickering NGS. Later he became Director of Nuclear Generation and, in 1991, Vice-President of Nuclear Operations.

New AECL Mission

In September, Bruce Howe, the new president and CEO of Atomic Energy of Canada Limited, announced a new "mission" for AECL:

> "We will secure the maximum economic benefit for Canada from the CANDU technology and associated R&D – the CANDU business."

He noted that AECL must be more commercial in its approach.

Gary Kugler has been appointed to head an AECL Corporate Task team that will include David Torgerson, Ian Hastings, Dan de Verteuil and Ray Grissold. The team's mandate is to "restructure, organize and staff the corporation and position it to achieve its mission in the most cost-effective and profitable way." The objective is to begin the transformation this year and complete it in the first half of next year.

Final Call for Papers

Third International Conference
on
Containment Design and Operation
19-21 October 1994, Toronto

Abstracts of 300 to 500 words, typed double space, should be submitted to:

Containment Design and Operation
Canadian Nuclear Society
144 Front Street West, Suite 725
Toronto, Ontario
M5G 2L7
Fax: (416) 977-8356

DEADLINE IS 30 NOVEMBER 1993

For information, contact:

Duane Pendergast
AECL CANDU
Tel: (905) 823-9049
Fax: (905) 823-8006

CNS Financial Statements
December 31, 1992

There was an error in the Financial Statements published in the last issue of the CNS *Bulletin*, Vol. 14, No. 2.

A corrected page is included in this issue. Please disregard the previous one.

Canadian Nuclear Society

Membership Application / Renewal Form

SURNAME ______ GIVEN NAMES ______ ☐ MR. ☐ MS. ☐ DR.

HOME ADDRESS ______

COMPANY/INSTITUTE/SCHOOL ______ STUDENT ☐

BUSINESS ADDRESS ______

CITY ______ PROVINCE ______ POSTAL CODE ______

PHONE (HOME) ______ PHONE (BUSINESS) ______ FAX ______

BUSINESS TITLE (IF APPLICABLE) ______ RETIRED ☐

IS CORRESPONDENCE TO BUSINESS ACCEPTABLE? ☐ YES ☐ NO REFERRED BY ______

CNS BRANCH TO WHICH YOU WOULD LIKE TO BELONG

- ☐ BRUCE
- ☐ CHALK RIVER
- ☐ GOLDEN HORSESHOE (Hamilton)
- ☐ MANITOBA
- ☐ NEW BRUNSWICK
- ☐ OTTAWA
- ☐ QUEBEC
- ☐ SASKATCHEWAN
- ☐ TORONTO
- ☐ CENTRAL LAKE ONTARIO (Pickering, Darlington, Port Hope, Peterborough)
- ☐ USA AND INTERNATIONAL

CNS DIVISION TO WHICH YOU WOULD LIKE TO BELONG

- ☐ NUCLEAR SCIENCE AND ENGINEERING
- ☐ DESIGN AND MATERIALS
- ☐ MINING, MANUFACTURING AND OPERATION
- ☐ WASTE MANAGEMENT AND ENVIRONMENTAL AFFAIRS

MEMBERSHIP TYPE AND FEE SCHEDULE FOR 1993†

☐ REGULAR	$55.00
☐ CHARTER	55.00
☐ STUDENT	20.00
☐ RETIRED	30.00
☐ INSTITUTIONAL	55.00

If you are a non-member and attend an event on the CNS Events Calendar, you are entitled to a $15.00 introductory discount on your first-year fees. Simply deduct $15.00 from your fees amount. ______
Please indicate name of CNS event.

METHOD OF PAYMENT

☐ CHEQUE ☐ VISA ☐ MASTERCARD ☐ AMEX

CARD NUMBER ______

EXPIRY DATE ______ SIGNATURE ______ DATE ______

Please send payment with this invoice now. Credit card payment may be faxed to (416) 979-8356. An official receipt will be sent in return.

Please complete and return to
The Canadian Nuclear Society, 144 Front St. W., Ste. 725, Toronto, Ontario M5J 2L7
Telephone 416-977-7620

Société Nucléaire Canadienne

Renseignements sur l'abonnement
Formulaire de renouvellement

NOM DE FAMILLE ______________________ PRÉNOM ______________________ ☐ M. ☐ Mme ☐ Dr

ADRESSE (DOMICILE) ______________________

COMPAGNIE/ÉCOLE/INSTITUT ______________________ ÉTUDIANT(E) ☐

ADRESSE DU BUREAU ______________________

VILLE ______________ PROVINCE ______________ CODE POSTAL ______________

N° DE TÉLÉPHONE (DOMICILE) ______________ (BUREAU) ______________ TÉLÉCOPIEUR ______________

TITRE (SI UTILISÉ) ______________________ RETRAITÉ(E) ☐

CORRESPONDANCE SERA ENVOYÉE AU BUREAU: ☐ OUI ☐ NON RÉFÉRÉ PAR ______________

SECTION LOCALE À LAQUELLE VOUS DÉSIREZ APPARTENIR

- ☐ BRUCE
- ☐ CHALK RIVER
- ☐ CROISSANT D'OR (Hamilton)
- ☐ MANITOBA
- ☐ NOUVEAU-BRUNSWICK
- ☐ OTTAWA
- ☐ QUÉBEC
- ☐ SASKATCHEWAN
- ☐ TORONTO
- ☐ LAC ONTARIO CENTRAL (Pickering, Darlington, Port Hope, Peterborough)
- ☐ ÉTATS-UNIS ET INTERNATIONAL

DIVISION TECHNIQUE À LAQUELLE OU AUXQUELLES VOUS DÉSIREZ APPARTENIR

- ☐ SCIENCE NUCLÉAIRE ET GÉNIE CIVIL
- ☐ CONCEPTION ET MATÉRIAUX
- ☐ EXPLOITATION MINIÈRE, FABRICATION ET EXPLOITATION DES CENTRALES
- ☐ GESTION DES DÉCHETS RADIOACTIFS ET ENVIRONNEMENTALES

TYPE D'ADHÉSION ET COTISATION POUR 1993†

☐ RÉGULIER	55.00 $
☐ FONDATEUR	55.00
☐ ÉTUDIANT(E)	20.00
☐ RETRAITÉ(E)	30.00
☐ INSTITUTIONNELLE	55.00

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

MÉTHODE DE PAIEMENT

☐ CHÈQUE ☐ VISA ☐ MASTERCARD ☐ AMEX

NUMÉRO DE CARTE ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

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

Calendar

1993

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

November 22-26 **Second Regional Meeting on Radiation and Nuclear Safety**
Zacatecas, Mexico
contact: Ing. R. Ortiz-Magana
Dr. Barragan N8779 Navarte 03020
Mexico D.F.
Tel.: 525-590-6103

December 3-4 **SIEN '93**
Bucharest, Romania
contact: Dr. H. Mccanu
AREN
CP 53 Code 76900
Bucharest, Magurele
Romania

1994

March ? **CNA/CNS Student Conference**
Toronto, Ontario
contact: Dr. Brian Cox
Centre for Nuclear Engineering
University of Toronto
Tel.: 416-978-2127

March ?? **Workshop on Information Technology**
Saskatoon, Saskatchewan
contact: E.G. Price,
AECL CANDU
Tel.: 905-823-9040 ext. 3066
Fax: 905-823-8821

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

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

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

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

April 24-27 **International Symposium on Decontamination and Decommissioning**
Knoxville, Tennessee
contact: Analyses Corp. Conference Management
Oak Ridge, TN, USA
Fax: 615-576-0709

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

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

May 17-19 **Annual Meeting on Nuclear Technology**
Stuttgart, Germany
contact: Dr. K.G. Bauer
INFORUM GMBH
Bonn, Germany
Fax: 49-228-5072-19

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

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

June 13-15 **2nd International Steam Generator and Heat Exchanger Conference**
Toronto, Ontario
contact: D. Lister, UNB
Tel.: 506-453-5138

June 19-24 **ANS Annual Meeting**
New Orleans, Louisiana
contact: Dennis Tolleison
Martin Marietta Energy Systems
P.O. Box 2009-8221
Oak Ridge, TN, USA 37831-8821
Tel.: 615-574-9877

August 14-18 **SPECTRUM 94 International Nuclear and Hazardous Waste Management Conference**
Atlanta, Georgia
contact: John Steele
Westinghouse Savannah River
Aiken, South Carolina, USA 29802
Tel.: 803-725-1830

September 12-16 **3rd International Symposium on Contribution of Materials Investigations to the Problems Encountered in Pressurized Water Reactors**
Fontrevaud (Chinon), France
contact: Ms. Christiane Moura
Société Française d'Energie Nucléaire
48 rue de la Procession
F75724 Paris Cedex 15, France

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October 2-6 — **ENC'94**
Lyon, France
contact: Dr. Peter Feuz
European Nuclear Society
Monbijoustrasse 5, P.O. Box 5032
CH 3001, Berne, Switzerland
Fax: 41-31-22-9203

October 19-21 — **3rd International Containment Conference**
Toronto, Ontario
contact: D. Pendergast
AECL-CANDU
Tel: 905-823-9040
Fax: 905-823-8006

November ?? — **Workshop on Life Extension**
Fredericton, New Brunswick
contact: Dr. Frank R. Wilson
UNB, Fredericton, NB
Tel.: 506-453-5189
Fax: 506-453-3522

November ?? — **Waste Management Conference**
Location to be announced
contact: Dr. C. Allan
Whiteshell Laboratories
Tel.: 204-753-2311
Fax: 204-753-2455

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May ?? — **International Conference on Isotopes**
Beijing, China
contact: Prof. Wang Dexi
Chinese Nuclear Society
P.O. Box 2125
Beijing, China, 100822
Fax: 85-27185

May 16-18 — **Annual Meeting on Nuclear Technology**
Nuremburg, Germany
contact: Dr. K.G. Bauer
INFORUM GMBH
Bonn, Germany
Tel.: 49-02-28-507-0
Fax: 49-02-28-5072-19

May 23-June 3 — **5th Topical Meeting on Tritium Technology in Fission, Fusion and Isotopic Applications**
Ispra, Italy
contact: E.G. Price
AECL CANDU, Mississauga, ON
Tel.: 905-823-9040 ext. 3066
Fax: 905-823-8821

September 10-15 — **NURETH-7 – International Meeting on Nuclear Reactor Thermalhydraulics**
Saratoga, NY
contact: Dr. Michael Z. Podowski
Rensselaer University, Troy, NY
Tel.: 518-276-6403
Fax: 518-276-4832

October ?? — **Fourth International Conference on CANDU Fuel**
Pembroke, ON
contact: Dr. Peter Boczar
Chalk River Laboratories
Tel.: 613-584-3311

November ?? — **3rd Conference on CANDU Maintenance**
Toronto, ON
contact: Mr. Tim Andreef
Ontario Hydro
Tel.: 416-592-3217
Fax: 416-592-7111

International Activities

Among the many activities that took place at the time of the INC '93 conference in Toronto, the Canadian Nuclear Society hosted a meeting of the **International Nuclear Societies Council** on October 3.

The INSC is a coordinating body with membership of most of the nuclear societies around the world, which have a total membership of over 40,000.

At the Toronto meeting the CNS was officially represented by president Paul Fehrenbach and past-president Bill Midvidy, with *Bulletin* editor Fred Boyd and Stan Hatcher as observers, (Current CNS International Affairs chairman, Ken Talbot, was unable to attend.)

Currently the INSC is chaired by Manning Muntzing, a former president of the American Nuclear Society, and the ANS provides the secretarial support.

A proposed statement on a "50 year vision" to examine the potential role of nuclear science and technology over the "second 50 years" of nuclear application evoked considerable discussion. Canadian member of the drafting committee, Stan Hatcher, argued that the outlook should be truly "visionary" while others suggested that it should focus on how nuclear could contribute to the betterment of human development.

The chairman noted the favourable response received from those involved with the IAEA sponsored International Nuclear Safety Convention on the report submitted by the INSC. That report was prepared by a special nuclear safety committee on which Bill Midvidy was a member. The Group of Experts on the Convention (chaired by Zig Domaratzki of the AECB) is meeting in Vienna the last week of October with the hope of finalizing the draft.

The convention will state broad principles to be followed by signatory nations and will probably focus initially on nuclear power plants (as recommended by the INSC) with provision to extend it to other nuclear facilities later.

The INSC decided to explore further a proposed international award for outstanding contributions to nuclear development and agreed, in principle, to accept as members the nuclear societies of Pakistan and Brazil. New members will be "invited" to endorse the INSC Global Creed (see last issue of the *Bulletin*).

A Directory of Nuclear Societies has been prepared. Copies could be obtained through the CNS.

The next meeting of the INSC will be held in Sydney, Australia, in conjunction with the 8th Pacific Basin Nuclear Conference, May 1994.

CNS Council • Conseil de la SNC

1993-1994

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  Al Lane (613) 584-3311
- **Design & Materials / *Conception et matériaux***
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- **Waste Management & Environmental Affairs / *Gestion des déchets radioactifs et environnement***
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John Reid (416) 977-6152

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Fred Boyd (613) 592-2256

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1993-1994

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Ottawa	Jeff Lafortune	(613) 563-2122
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Saskatchewan	David Malcolm	(306) 665-6874
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