CANADIAN NUCLEAR SOCIETY

Bulletin

DE LA SOCIÉTÉ NUCLÉAIRE CANADIENNE

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Recruit a new member

Membership chairman Jerry Cuttler is out to expand the Society and as an incentive is offering a CNS tie or scarf to every sponsor of a new member.

A membership form is included with this issue of the *Bulletin* to assist you in your recruiting.

CNS office moving

On 1 August 1991 the offices of the Canadian Nuclear Association and the Canadian Nuclear Society will move to:
144 Front St. W., Suite 725
Toronto, Ontario M5J 2L7

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Bulletin

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

CNS provides Canadians interested in nuclear energy with a forum for technical discussion. For membership information, contact the CNS office, a member of the Council, or local branch executive. Membership fee is $55.00 annually, $25.00 to retirees, $15.00 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 $, 25.00 $ pour les retraités, et 15.00 $ pour les étudiants.

Editor / *Rédacteur* (613) 592-2256
Fred Boyd Fax (613) 820-3593

Domestic Program Essential

The announcement from AECL CANDU of the decision by Korea Electric Power Company to build Wolsong 2 was welcome news to the many members of our Society directly or indirectly affected by the project.

Having some direct awareness of the Korean scene the sale can truly be noted as an accomplishment of persistence. AECL has maintained a presence in Korea since the Wolsong 1 project, despite many periods of pessimism. That continuous presence and positive co-operation with Korean technical groups, together with the good performance of Wolsong 1, convinced the very business-oriented, value-conscious officials of KEPCO that CANDU was a very desirable element of the Korean nuclear power program. (They have 12 PWR's operating or under construction.)

While such persistence is necessary for foreign sales it will not be sufficient if our own domestic program is not on-going and vigorous. There are many reasons for the current lack of support for nuclear projects in this country, including the economic recession and political uncertainty. An underlying cause, however, is the widespread perception that we do not need nuclear power – in fact that we do not need any additional electricity generation.

This is a problem members of the CNS can help address. While our numbers are not large, if every member took every opportunity to explain the need for additional energy production and the advantages of nuclear, we can probably have a ripple effect.

The CNS Council has registered as a participant in the hearings to be held by the Environmental Assessment Board on Ontario Hydro's Demand/Supply Plan. Individuals can also submit comments or ask to appear. Given the dynamics of such hearings it could well be that a number of submissions by "concerned citizens" will have more impact than a formal presentation by an identified organization.

Their Future is Ours

From time to time an event comes along that helps bolster your belief in the future. The recent CNS Student Conference was such an occasion.

It was a well-organized, well-run affair – to the point that many older members of our Society could take lessons. But what was most inspiring was the obvious enthusiasm of those students for their subjects. Nuclear technology clearly presented for them an intellectual challenge which they were eager to take on.

This led to a nagging and disturbing question – will they, when they graduate, all find appropriate positions where they can apply their knowledge and enthusiasm?

According to a recent consultants' report, which the CNA/CNS Education and Human Resources Committee is studying, there will be a shortage of nuclear engineers by the end of the decade. There are obviously many assumptions in such a prediction but if our current graduates can not find proper jobs there is no doubt that the number of students choosing nuclear programs will diminish even further. The "supply" of engineers will not, can not, respond quickly to a new "demand" when society finally realizes its need for energy (a point that economists seem incapable of understanding). Hopefully the CNA/CNS committee will look at this aspect (current employment opportunities) as well as ways to entice young people into nuclear programs.

Communication

Communication, or the lack of it, is often identified as a major contributor to misunderstandings, disagreements and distrust. Poor communication is, undoubtedly, one of the causes of the public dislike of, or even fear of, things "nuclear."

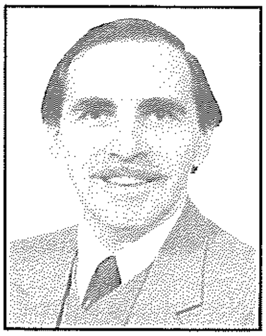
It is ironic, therefore, and sad to observe the total absence of communication between two professional groups both concerned with the use of nuclear energy in Canada – our Society and the Canadian Radiation Protection Association.

An example of this isolation is that neither the CNS nor the CRPA calendars of events list the annual meeting of the other group, and this despite the fact that this year both are in western Canada and come one after the other in June – the CNS's, of course, in Saskatoon, June 9 - 12 and the CRPA's in Winnipeg from June 16 - 19. Is this another case of "two solitudes"?

Any reader who is interested in the new dose limits or any other aspect of radiation protection might consider attending the CRPA meeting after the CNS conference.

For information call (204) 474-6633 or FAX (204) 275-5863.

Note du Président



Hugues W. Bonin

La Société Nucléaire Canadienne est le théâtre de plusieurs évènements excitants récemment. Votre humble serviteur vient de recevoir un coup de fil du Dr Al Wight au sujet de la Conférence annuelle de la SNC, qui aura lieu à Saskatoon les 9 au 12 juin 1991, pour ne pas faire de publicité. La sélection des communiqués vient d'être complétée et le programme technique aura définitivement un succès boeuf! (Le Jeu de mots était prémédité...) Nous pourrons assister à 96 présentations. La réponse à l'appel aux communications fut telle qu'il a fallu consolider certaines d'entre elles et, malheureusement, en refuser quelques-unes, afin de respecter les contraintes de l'horaire. Beau travail!

Au moment où je rédige cet article, le 16e Colloque Étudiant annuel de l'ANC et de la SNC est déjà chose du passé. Il me fait plaisir de rapporter que ce fut un succès mur à mur, grâce aux nombreux participants et aux efforts dévoués des Élèves-Officiers du Royal Military College, à ses étudiants de cycle supérieur, à ses professeurs et à son personnel de soutien, et, bien sûr, à l'ANC et à la SNC qui commanditaient le Colloque. Plus de 55 étudiants, professeurs et professionnels ont entendu les 26 orateurs et les deux conférenciers invités, le Dr Glen McGillivray de Chalk River, et M. Gordon Sims, auteur de récent livre «The Anti-Nuclear Game.» En plus d'un banquet et d'un déjeuner, les participants ont assisté à l'inauguration officielle de l'Installation de Radiographie Neutronique du Laboratoire Nucléaire SLOWPOKE-2 du RMC. Notre Rédacteur, M. Fred Boyd, était présent et vous présentera un court rapport de la conférence ailleurs dans ce *Bulletin*. Un grand merci à tous!

Une troisième activité a été la contribution de la SNC au Forum des Citoyens sur l'Avenir du Canada, à la suite d'une lettre de M. Keith Spicer invitant notre contribution. Nous avons préféré procéder par voie d'un bref exposé écrit qui apparaître dans ce numéro du *Bulletin*. Plusieurs des membres du Conseil ont contribué à la rédaction d'un texte dans lequel le point de vue a été volontairement restreint à la perspective du développement de l'énergie nucléaire. Le texte peut apparaître comme une tentative exagérée de vanter les succès canadiens dans harnachement de l'énergie nucléaire, mais, après tout, qui d'autre aura vendre les mérites du nucléaire ces jours-ci?

Le lecteur apprend par la suite que le Canada est le seul pays du monde, avec les États-Unis, à avoir réussi à développer un réacteur nucléaire de puissance «indigène» qui soit toujours commercialement compétitif, comme le démontre la récente vente d'un CANDU à la Corée. (La France, le Royaume-Uni et l'URSS ont développé des réacteurs modérés au graphite dans le passé, mais en ont subséquemment abandonné le développement en faveur du réacteur à eau légère). Le document reconnaît qu'un tel succès a été rendu possible dans un Canada unifié, où de fortes institutions ont assuré la réalisation de projets de cette dimension en rassemblant les ressources humaines et financières essentielles. Le texte conclut en affirmant, d'après les leçons de l'histoire, qu'il est préférable, du point du développement de l'énergie nucléaire, que le Canada reste un pays uni, sans toutefois déclarer qu'un pays fragmenté ne signifierait pas nécessairement la fin du développement fructueux de la technologie nucléaire. Le texte ne traite pas des moyens de préserver l'unité canadienne, vu que mes collègues du Conseil et moi-même ne croient pas qu'il soit de notre mandat de traiter de ces questions socio-politiques. On a plus d'experts et d'«experts» dans ces domaines qu'il ne faut pour cette tâche!

Votre Conseil va se rencontrer encore une fois le 4 avril prochain à Saskatoon, pour surtout discuter de la Conférence annuelle. L'agenda de la réunion est bien pourvu de sujets de discussion, mais nous sommes toujours ouverts aux suggestions et aux commentaires. Notre Présidente Sortante, Dr Eva Rosinger, a déjè commencé de s'occuper de l'élection du nouveau Conseil. La SNC peut certes utiliser toutes les ressources disponibles: n'hésitez pas à vous porter volontaire pour l'un des postes. Enfin, un rappel: vous avez certes reçu le feuillet intitulé: «Innovative Achievement Award.» (La version française s'en vient.) Il est encore le temps de soumettre les noms de candidats pour cette récompense. Vous avez certainement des collègues dans votre entourage qui la méritent. Un petit effort de votre part est tout ce qu'il faut!

Hugues W. Bonin
Président

Message from the President

Exciting events are happening at the CNS. Yours truly got recently a phone call from Dr. Al Wight about the up-coming Annual Conference (Saskatoon, 9-12 June 1991). The paper selection has been completed and we will enjoy quite a beefed-up technical program (pun intended): a whopping 96 papers will be presented! Indeed, several papers had to be consolidated or refused in order to fit the timetable constraints. Great work!

At the writing of these few lines, the 16th Annual CNA/CNS Student Conference is just over. It is a pleasure to report that it has been a wall-to-wall success, thanks to the many participants and especially to the devoted efforts of the Royal Military College Officer-Cadets, Graduate Students, teaching personnel and support staff and, of course, to the CNA and CNS, co-sponsors of this event. More than 55 students, professors and professionals listened to the 26 speakers and the two keynote speakers, Dr. Glen McGillivray from Chalk River, and Mr. Gordon Sims, author of "The Anti-Nuclear Game." In addition to a banquet and a luncheon, the participants attended the official inauguration of the Neutron Radiography Facility at the SLOWPOKE-2 Nuclear Laboratory at RMC. Our Editor, Mr. Fred Boyd, was present and will report elsewhere in this *Bulletin*. Many thanks to all!

A third activity has been the contribution of the CNS to the Citizens' Forum on the Future of Canada, following a letter from Mr. Keith Spicer requesting our contribution. We preferred to submit a brief that will appear in this issue of CNS *Bulletin*. Several Council members contributed to the writing and agreement was eventually reached for a text in which the point of view was voluntarily restricted to the nuclear energy development perspective. The text may appear to oversell the Canadian successes in harnessing nuclear energy, but, after all, who else will do the salesman job for us? The reader learns that Canada is the only country of the world, with the United States, to have successfully developed an indigenous nuclear power reactor that is still commercially viable, as the recent sale to Korea demonstrates. (France, the United Kingdom and the USSR have developed graphite-moderated reactors in the past, but have abandoned further development in favour of the LWR.) The brief acknowledges that such a success has been made possible within a unified Canada, where strong institutions made possible the realization of such a grand project by gathering the necessary teams of experts and the financing to sustain it. The text concludes by stating that, based on the lessons of history, it is preferable, from the point of view of the nuclear energy development, that Canada remains a united country, although a fragmented country does not necessarily preclude continued successful development of the nuclear technology. The brief does not address the question of how to maintain the Canadian Unity, as my colleagues on the Council and myself do not feel it is our mandate to deal with these socio-political questions. There are more than enough experts and 'experts' in these fields to do this job.

Your Council meets April 4th in Saskatoon, with the main topic of the meeting being the Annual Conference. The agenda is well stuffed with other subjects, but we are always open to suggestions and comments. Our Immediate Past President, Dr. Eva Rosinger, has already been tasked to look after the election of the next Council. We can use all the resources available: don't hesitate and get involved! Finally, a reminder: you must have received by now the leaflet entitled "Innovative Achievement Award." There is still time for submitting names of candidates by the April 30th 1991 deadline. There are surely colleagues around you who deserve to have their work recognized. A little effort on your part is all that is needed!

Hugues Bonin
President

The CNS/CNA Student Conference served as the setting for the official inauguration of the Neutron Radiography Facility at the SLOWPOKE-2 reactor at the Royal Military College, Kingston. Here Dr. Glen McGillivray, of the Chalk River Laboratories, joins with Dr. John Plant, Principal of RMC, in the ribbon-cutting ceremony, March 22. Photo courtesy of RMC

Canadian Fusion Fuels Technology Project

The Canadian Fusion Fuels Technology Project (CFFTP) is a key centre of Canada's National Fusion Program and is funded by the Government of Canada, the Government of Ontario and Ontario Hydro. It is dedicated to the development and application of fusion technologies to Canadian and international fusion projects.

Student Awards

Award Description

The "CFFTP Student Awards" consist of three $1,000 grant awards. Up to three students will receive the award annually in September. Two of these awards will be granted for studies directly related to fusion energy and the third award will be granted for studies in science or engineering indirectly related to fusion energy.

The award will recognize outstanding University students involved directly or indirectly with fusion energy and who have demonstrated a high level of accomplishment in their studies.

Selection and Eligibility Criteria

Criteria to be used in the selection procedure will include, but are not limited to:

a) the nominee's grades for the two years preceding the nomination,

b) the quality, substance and originality of a project or thesis report produced as part of the normal course work, and

c) other papers and supplementary information on the nominee's accomplishments.

The nominee must be a Canadian citizen or landed immigrant, enrolled in a science or engineering course at the undergraduate or graduate level at a recognized Canadian University. Applications will be assessed on the basis of what is expected from a student at his / her particular level and would be of most interest to students who are currently at the Master's level or final year undergraduate level.

Application Procedure

Applications will be accepted until June 30th of each year for award the following September and are to be made by letter to:

CFFTP Student Awards Panel
Canadian Fusion Fuels Technology Project
2700 Lakeshore Road West
Mississauga, Ontario L5J 1K3
Tel: (416) 855-4701 • Fax: (416) 823-8020

The letter of application must provide a brief rationale in support of the application and must be endorsed by the applicant's University supervisor or a member of the faculty who is familiar with the applicant's work. For completeness the application should include the information described above under Elegibility Criteria. The Awards Panel may elect in any given year not to make an award if there are no suitable candidates.

CFFTP is offering Fusion Technology Fellowships to support graduate studies and research in fusion technology. The program seeks to unite university research with established fusion R&D projects through jointly sponsored research and *practicum* assignments.

Fusion Technology Fellowships

Description

The Fellowship consists of a stipend up to $10,000 / annum, plus tuition, payable in two equal instalments. It is renewable annually subject to achievement. The value of the Fellowship will be reduced such that the total value of all fellowships received by the recipient will not exceed $20,000 per year. The recipient will be limited to no more than 300 hours per year of teaching duties.

During the Fellowship, special assignments of the recipient to a fusion-related R&D project either within or outside Canada may be arranged to provide practical experience that contributes to the student's thesis. Such assignments would typically be for 3-4 months with additional financial compensation provided to cover incremental costs. Potential sites for such *practicum* assignments include Chalk River Nuclear Laboratories, Ontario Hydro Research Division, Centre canadien de fusion magnétique, selected industries, national laboratories, universities and foreign fusion projects.

Eligibility

The applicant must be pursuing or entering a Masters or Doctorate degree program and must be a Canadian citizen or landed immigrant. The topic of study must be related to fusion technology. The following is a partial list of relevant fusion technology areas:

- fusion fuels (tritium) processing and handling
- fusion blanket technology
- fusion materials science and technology
- fusion reactor systems engineering
- fusion safety
- remote handling technology in fusion reactors
- other areas of applied fusion science and engineering

Application

Applications should be made directly to CFFTP at the address below stating interests, qualifications, including transcripts, the names of two references, the name of the university where the Fellowship will be held, the name of the supervising professor and the proposed research topic. A separate statement of support for the project from the supervising professor may be requested. Applications should be received at:

Canadian Fusion Fuels Technology Project
2700 Lakeshore Road West
Mississauga, Ontario L5J 1K3
Attention: Fusion Technology Fellowship Program
Tel: (416) 855-4701 • Fax: (416) 823-8020

no later than June 1st for tenure starting the following September. Students who are in the final year of their undergraduate program and who are anticipating entering graduate studies are invited to express interest for consideration.

A Comment on the Spicer Commission

Daniel Rozon

Ed. Note: *Although this note was addressed to the CNS Council, Dr Rozon, who is Directeur de l'Institut de génie énergique de l'École Polytechnique de Montréal, suggested that it might be published in the* Bulletin *for the information of all CNS members.*

As always your comments are invited.

During the last Council meeting, I voiced some concern when it was decided to respond to the invitation from the Citizens' Forum on Canada's Future (Spicer Commission). Although I did not make myself very clear on that occasion, I am not very comfortable with the idea of mixing federal politics with the affairs of the Society. However, I realize that the present context is exceptional, and it is proper for us to participate in the Forum. The following comments were prepared on the basis of the first draft of the brief. I subsequently received the final draft, and the revisions have been noted. Please note that my comments are of a general nature and are not intended to influence the final content of the brief.

First of all, I think the draft prepared for the Spicer Commission was well written. The brief is balanced and offers convincing economic arguments for Canadian federalism. More importantly, it derives a sense of national pride from our achievements with the CANDU, linking these achievements to the federal framework within which it was developed. I certainly do not object to the submission of the brief as it stands, for I suspect it reflects the opinion of the large majority of the membership.

I would like to submit to Council members some of my personal views on the main issue, if only to clarify my discomfort with the position taken in the first draft of the brief. In particular, I had some difficulties with the suggestion that "our emotional ties, our common experiences and our great achievements" within the present framework warrant *by themselves* the pursuit of a united Canada with a strong national government. However, there are other issues involved which might become overriding. In the final draft, the above statement was revised to propose instead that "a united Canada would continue to benefit our nuclear energy program." I agree with this, and in fact I believe that most of the constitutional arrangements proposed by Québec (short of outright secession) can accommodate a national nuclear energy program.

As far as I see it, emotional ties to Canada are essentially different for French Canadians, especially for the Québécois whose motto is "Je me souviens." To the basic question asked by the Commission (i.e., what makes us Canadians?), most Québécois will evoke notions of a great country first founded by their ancestors (on land previously ruled by native people) and shared (albeit unwillingly) with the new Canadians, of a country they helped to build during the first hundred years of Confederation with the tacit understanding that every Canadian is equal under the law, regardless of colour, race, religion or culture. I also believe that most Québec nationalists recognize that modern Canada could not have evolved to its present greatness if it were not for the exercise of effective centralized federal powers and for the immense contribution to Canada of other nations through immigration.

In 1982, with repatriation of the constitution, an effort was made to define those basic individual rights applicable to every Canadian and which define us as a civilized nation. However, a grave omission was allowed to occur, in that the basic law does not recognize the Québécois perception that our country is historically based on a pact between two nations, and that one of these nations is mainly situated in the province of Québec where it holds limited legislative powers. The gravity of the gesture was compounded by the fact that it occurred only two years after the Québec referendum, when renewed federalism was chosen as a solution to the legitimate concerns of a large segment of the Québec population regarding the security of its culture *and* of its national identity under an entrenched centralized majority rule. As the Meech Lake saga quickly showed, native people also have some reservations about national identity. The whole process is now in a deadlock because (in my view) of the perception of some Canadian regions which view the Québec position as a threat to their own legitimate demands for renewed federalism.

These concerns are very serious. They cannot be abated by reducing or assimilating Québec demands to a desire for "better control over language, culture and local business." I think Premier Bourassa was right when he stated last June 24 that the Québécois view themselves as a people free by their own choice, free to assume their own destiny. This is a fact of modern Canadian life. It may be a grand illusion, but it would be a grave political mistake to suggest that the obvious economic advantages of strong federal institutions outweigh the need for a national identity in which every citizen is able to recognize himself or herself. In fact, I was particularly impressed by the arguments used by many Canadians during the free trade debate for their resemblance with arguments used by Québec nationalists within the Canadian federation.

The aspirations of what appears to be a majority of Québec citizens are certainly not meant to alienate the rest of Canada. Nor are they inspired by some desire for more regional power at the detriment of other regions. I think that what Québec basically wants is to be treated as an equal partner within the federation while preserving its cultural sovereignty (i.e. *final* control of cultural sectors such as language, education, communications, immigration, social programs, etc. . . .). This is not simply a case of "having your cake and eating it too." What I hope is that we will not be forced to choose between the two, for surely then we will all be losers.

Council is free to file my personal views with the Citizens' Forum.

A Brief to the Citizens' Forum on Canada's Future from the Canadian Nuclear Society

Ed. Note: As mentioned in the Message from the President, the CNS Council decided to respond to an invitation from Keith Spicer by submitting a brief to the Citizens' Forum on Canada's Future which he chairs.

Following are both the English and French versions of the proposed brief. Council welcomes your comments.

Summary

The Canadian Nuclear Society strongly supports an amicable solution to our constitutional crisis which would allow the people of Quebec and of other provinces / regions to feel comfortable as Canadians. The potential separation of Quebec would greatly diminish its significance and that of the remainder of the country, creating barriers to communication and weakening the bonds of co-operation. It was the pooling of resources and the co-operation of the provinces that enabled Canada to develop the heavy water nuclear power reactors that were unique and in many ways superior to the light water reactors that the Americans developed. A united Canada with a strong national government will enable our nuclear energy industry to exploit new opportunities and meet the challenges of the future.

Canadian Nuclear Society

The CNS is a learned society of nearly 700 scientists, engineers and other professionals in the nuclear domain. Its purpose is to foster the exchange of knowledge and ideas through formal conferences, seminars and courses and by means of the activities of its nine branches in five provinces. By publishing the quarterly CNS *Bulletin*, the Canadian Nuclear Society keeps its members informed of Canadian events, publications and news in the nuclear field. The CNS also associates with similar societies in the United States and overseas, giving its members access to international events and opportunities. The Canadian Nuclear Society is bilingual, and all participants to its conferences and symposia may submit their technical papers in either French or English.

Our members work in an industry which harnesses nature's most fundamental energy source, returning matter to the energy from which it came at the creation of the universe. This nuclear energy is also being released by our sun, the primary source of energy that made life on earth possible. We work in research, development and design centres in Manitoba, Ontario and Quebec, in the Saskatchewan and Ontario uranium industry, in the Ontario, Quebec and New Brunswick utilities which generate 17% of Canada's electricity from our uranium, and we work in the manufacturing and processing industries across the country who apply state-of-the-art production technology to supply the components and materials upon which this industry depends. Collectively, our activities represent 50,000 jobs and a major fraction of Canada's "high technology" economy.

Canada's Nuclear Technology

Because of the farsightedness and national purpose of our country's leadership 50 years ago, Canada embarked upon a national program of research and development which has resulted in our being the only country outside of the United States to have developed a commercially viable technology for producing reliable electricity, without pollution, from our most abundant energy resource.

The CANDU nuclear power system is almost universally acknowledged as being superior to other nuclear power technologies in the key areas of safety, availability and fuel utilization. Its ability to "burn" waste fuel from other reactor systems as well as naturally-occurring thorium is unique, offering the prospect of greatly extending the world's energy resources and reducing the amount of radioactive waste to be stored.

In addition to the CANDU technology, Canada has developed many research reactors, six of which are located in our universities, and is currently developing the SLOWPOKE Energy System to provide hot water district heating in urban areas without pollution.

Canada has been a pioneer in the use of radiation in cancer treatment and in diagnostic techniques in nuclear medicine, and is currently one of the advanced nations in this area. Our country is a leader in many industrial applications of radiation and radioisotopes, such as food preservation, sterilization, chemical processing, waste water treatment, non-destructive testing and analysis methods. Some of the instruments used by United Nations inspectors to verify compliance with the Non-Proliferation Treaty are Canadian inventions. It is to be noted here that all Canadian research and development activities in the nuclear domain are devoted to peaceful uses of nuclear energy.

International Competition

Because of the co-operation of our talented people and the support of our government, we have been able to develop these advanced technologies at a low cost compared to the research and development outlay of any of the major industrial powers in nuclear energy. The recent decision of Korea, one of the world's most sophisticated and successful economies, to commit to a long-term role for CANDU is evidence that Canada can compete with the most powerful industrial nations.

By developing a successful nuclear energy system (instead of adapting an American one), we have accomplished, as a nation, an achievement which the Soviet Union, France, the United Kingdom, Italy and China have attempted, but not yet done. We could not have done this without the magnificent sense of purpose and will which our leaders and citizens displayed during the 1940s and 1950s when CANDU development was but a dream. We have demonstrated the ability to transfer and implement this technology in distant locations such as Argentina, where its performance has been exceptional. In the last two years, the CANDU at Embalse, Argentina, has performed in the top ten percent of the world's reactors, while producing almost fifteen percent of Argentina's electricity.

Challenges

The accidents at Three Mile Island and Chernobyl have been publicized by the news media far out of proportion to the actual number of fatalities and the real adverse health effects which are much less than those of common industrial accidents. This has frightened many people into imagining terrible accidents at every other nuclear station, even though the designs are much safer, and the lessons learned from these accidents have been incorporated to make the stations even more secure.

In addition, a tiny minority of vocal activists has carried on a sustained campaign of misinformation and been partly successful in raising public fears of accidents, radiation, nuclear weapons proliferation and radioactive waste disposal.

Although the vision has been tarnished in the public's perception, Canada has risen magnificently to all of these challenges. We continue to improve the safety of our reactors even though they already meet the highest standards. We have responded to explain how low the radiation levels really are and that the fears are unwarranted. We have led and pioneered the establishment of an increasingly effective non-proliferation regime, which continues to gain international acceptance and commitment. The influence of our diplomats has been immeasurably enhanced by our status as the first nation with a comprehensive nuclear program and capability for peaceful uses uniquely. We have also led in the development of technologies for monitoring the use and storage of nuclear materials in order to assure non-proliferation.

Canada has led in the development of technology for the permanent and safe disposal of used nuclear fuel in rock formations such as those which make up most of the Canadian Shield. The Canadian fuel waste management program has been monitored throughout its work by an advisory committee of independent experts appointed by Canada's learned societies, and the proposed disposal concept is now undergoing assessment in a public forum.

Canada has one of the most independent, capable and highly regarded regulatory agencies in the world. It monitors, inspects, licences and regulates all activities in Canada related to nuclear technology.

Opportunities

As we approach the twenty-first century we are faced with daunting challenges in providing for all of mankind an acceptable quality of life on a basis which is sustainable from a resource and environmental viewpoint. Canada has the means, physical and intellectual, to make a major contribution to meeting these challenges. Our nuclear technology and skills are part of these resources.

National Dimension

The achievements of Canadian nuclear science, technology and business are a source of national pride. They could not have been accomplished on the basis of less than a national commitment of resources and the involvement of dedicated scientists and engineers from across Canada and all of its cultures. The nuclear industry is but one dimension of our accomplishments as a nation. We would all be diminished in our ability to maintain and participate in such grand enterprises by its fragmentation.

Quebec manufactures major parts of the CANDU reactor, including the reactor vessel itself. Major architect / engineering firms reside in Quebec and have participated in CANDU megaprojects. The potential separation of Quebec, in the free-trade environment, could regrettably affect traditional partnerships to the detriment of future CANDU projects. Each project provides many hundreds of millions of dollars in orders to Canadian suppliers and employment for many thousands of Canadian people for several years.

The CANDU nuclear power system needs the resources and the market of a large home economy to succeed. This is clearly apparent from our unfortunate experience with the Arrow aircraft. CANDU has captured 5% of the world nuclear power market, which is remarkable in the face of the difficult competition, but most of the CANDU reactors were installed in Canada. Weakening the country weakens this market. Canada has traditionally been a supplier of natural resources for manufacturing industries in the United States and abroad. The development of the CANDU has helped transform our country into a supplier of high-tech manufactured products and engineering services as well.

It is difficult to imagine how our nuclear power program could have developed without the support of a strong national government to support research and development and to help market and finance nuclear projects in Canada and abroad. If Canada is broken up or if the national government is significantly weakened, there would be a major impact on this capability. How easily could a new high-tech industry start up in a fragmented political environment?

Historically, many people (in Quebec particularly) contributed to the field of nuclear science and engineering. They helped apply this technology to production, medicine and other areas. Political unity and bilingualism promoted communication, co-operation and the sharing of work which were very important for the success of the nuclear energy program. Political separation creates barriers to communication and weakens the bonds of co-operation.

The Canadian Nuclear Society has strongly promoted bilingualism and co-operation among our colleagues from sea to sea. We believe that a united Canada with a strong national government would continue to benefit our nuclear energy program. We also understand that the French-Canadians, totalling a quarter of Canada's population and living in all provinces, have legitimate reasons to fear for the survival of their culture and language and to seek, among others, better control over language, culture and local business. Lessons should be learned from the recent collapse of the Meech Lake Agreement. This should be viewed as a rare occasion in Canadian history where all provinces agreed on a constitutional document, only to have ratification denied as a result of weaknesses in the amendment procedure and of unfortunate actions of some politicians who took advantage of these weaknesses to promote local interests at the expense of Canadian unity and harmony.

Now is the time for our leaders to rise to the great challenge that faces our country and create the constitutional compromise necessary for a long-lasting and mutually-beneficial relationship between the provinces. The CNS, with our nation-wide representation, is interested to assist in identifying potential solutions that would maintain or enhance the success of our country and our nuclear energy industry, which are so interdependent.

Énoncé de Point de Vue de la Société Nucléaire Canadienne au Forum des Citoyens sur l'Avenir du Canada

Résumé

La Société Nucléaire Canadienne supporte ardemment une solution à l'amiable à notre crise constitutionnelle qui pourrait permettre aux habitants du Québec et des autres provinces ou régions de se sentir à l'aise comme Canadiens. Une séparation potentielle du Québec diminuerait grandement son importance et celle du reste du pays, en créant des barrières aux communications et en affaiblissant les liens de coopération. C'est en mettant à l'unisson les ressources et la collaboration des provinces que le Canada a pu développer les réacteurs nucléaires à eau lourde (CANDU) qui sont uniques et, sous plusieurs aspects, supérieurs aux réacteurs nucléaires à eau légère créés par les Américains. Un Canada uni avec un gouvernement national fort va permettre à l'industrie de l'énergie nucléaire d'exploiter de nouvelles opportunités et de rencontrer les défis du futur.

La Société Nucléaire Canadienne

La Société Nucléaire Canadienne est une Société Savante de quelques 700 scientifiques, ingénieurs et autres professionnels du domaine du nucléaire. Sa raison d'être est de promouvoir l'échange d'idées et de connaissances par le biais de conférences, de symposia ou de cours, et au moyen des activités de ses neuf sections locales disséminées dans cinq provinces. La SNC publie le «*Bulletin de la SNC*» quatre fois l'an, afin de tenir ses membres informés des derniers événements sur la scène Canadienne et internationale, des récentes publications et des nouvelles du nucléaire. La SNC a aussi signé avec d'autres Sociétés Nucléaires (américaines et d'autres pays) des documents de coopération qui permettent à ses membres l'accès à des manifestations et opportunités sur la scène internationale. La SNC est bilingue, et tous les participants à ses conférences et symposia sont invités à y présenter leurs communications techniques en Français aussi bien qu'en Anglais.

Nos membres oeuvrent au sein d'une industrie qui harnache la source d'énergie la plus fondamentale de la nature, retournant la matière à l'énergie dont elle est issue. Cette énergie nucléaire est celle générée par notre Soleil, la source d'énergie primordiale qui a rendu la vie possible sur la Terre. Nous travaillons surtout aux centres de recherche, de développement et d'ingénierie du Manitoba, de l'Ontario et du Québec, dans l'industrie de l'uranium de la Saskatchewan et de l'Ontario, et au sein des sociétés de production d'électricité de l'Ontario, du Québec et du Nouveau-Brunswick, qui génèrent 17% de toute l'électricité Canadienne à partir de la fission de notre uranium. Nous oeuvrons aussi au sein de l'industrie manufacturière et de transformation, partout au pays, où l'on applique la technologie de pointe pour la production de composante et de matériaux dont dépend l'industrie nucléaire. Collectivement, nos activités représentent 50,000 emplois et une fraction majeure de l'économie Canadienne et «haute technologie».

La Technologie Nucléaire du Canada

Grâce à la prévoyance et au sentiment de devoir national des dirigeants du Canada il y a 50 ans, notre pays s'est lancé dans un programme national de recherche et de développement dont le résultat est que, maintenant, nous sommes le seul pays, hormis les États-Unis, à avoir créé et développé une technologie nucléaire originale et commercialement viable pour la production d'électricité, sans pollution, et de manière sûre, à partir de notre ressource énergétique la plus abondante.

La filière nucléaire CANDU est reconnue presque unanimement comme étant meilleure que les autres filières en termes de sécurité, de disponibilité et d'utilisation du combustible. Ce réacteur peut «brûler» du combustible usé retiré de réacteurs à eau légère notamment, et peut même utiliser du thorium naturel comme combustible, ce qui offre des perspectives de prolonger grandement les ressources énergétiques du monde, et de réduire les quantités de déchets radioactifs à être entreposés.

En plus de la filière CANDU, le Canada a développé plusieurs types de réacteurs de recherche, dont six se trouvent dans nos universités, et est présentement à mettre au point le réacteur SLOWPOKE Energy System conçu pour fournir le chauffage par eau chaude (et parfois aussi de l'électricité) à des ensembles urbains sans pollution appréciable.

Le Canada a été un pionnier dans l'utilisation de la radiation pour la traitement du cancer, et en médecine nucléaire dans les techniques de diagnostic, et est présentement l'une des nations les plus avancées dans ce domaine. Notre pays est à l'avant-garde dans plusieurs applications industrielles de la radiation et des radio-isotopes, telles que dans la préservation des aliments, la stérilisation, la chimie sous radiation, le traitement des eaux usées, les méthodes d'essai non-destructif et les techniques d'analyse. Certains des instruments utilisés par les inspecteurs des Nations-Unies pour vérifier le respect du Traité de Non-Proliferation des Armes Atomiques sont des inventions Canadiennes. On doit se rappeler ici que toutes les activités de recherche et de développement Canadiennes dans le domaine du nucléaire sont pour des utilisations pacifiques de l'énergie nucléaire.

Compétition Internationale

Grâce aux efforts de nos gens talentueux et au support de notre gouvernement, nous avons été capables de développer ces technologies de pointe à un coût plus bas que celui associé aux programmes de recherche et de développement dans le nucléaire pour les autres puissances industrielles majeures. Une preuve de la compétitivité du Canada avec les autres grandes nations industrielles est la récente décision de la Corée, dont l'économie est l'une des plus sophistiquées et des plus florissantes, de confier au CANDU un rôle à long terme dans la production de son électricité.

En développant une filière nucléaire réussie, (au lieu de simplement adapter la filière Américaine), nous avons accompli comme nation ce que l'Union Soviétique, la France, le Royaume-Uni, l'Italie et la Chine ont tenté, mais pas encore réussi. Ceci n'aurait pas été possible sans ce sens magnifique de devoir national et de volonté que nos concitoyens et nos dirigeants des années quarante et cinquante ont déployé quand le CANDU n'était alors qu'un rêve. Nous avons démontré que nous pouvions établir notre technologie dans des pays lointains comme l'Argentine, où la performance du CANDU de la centrale d'Embalse est exceptionnelle, ce réacteur s'étant classé parmi les meilleurs réacteurs au monde ces deux dernières années, tout en produisant à lui seul quelques 15% de l'électricité de ce pays.

Défis

Les accidents de Three Mile Island et de Chernobyl ont reçu une publicité dans les médias totalement hors de proportion avec leurs conséquences, en termes de décès, de blessures et d'effets néfastes à la santé, qui furent beaucoup moindres que celles d'autres accidents industriels plus communs. Le traitement médiatique de ces deux accidents nucléaires a semé la panique dans la population en évoquant le spectre d'accidents terribles à toutes les autres centrales nucléaires, sans aucune considération pour les concepts plus sûrs et les systèmes de sécurité plus performants dont sont équipées nos centrales.

De plus, une petite minorité d'activistes bruyants a soutenu une campagne de désinformation et a réussi, en partie, à susciter dans le public des craintes non fondées des accidents, de la radiation, de la prolifération des armements nucléaires et de la disposition des déchets radioactifs.

En dépit du ternissement de la vision dans la perception du public, le Canada a fait face à ces défis de façon magnifique. Nous continuons à améliorer la sûreté de nos centrales nucléaires, même si cette sûreté est présentement aux plus hauts niveaux de standards. Nous avons réussi à répondre aux craintes du public et à le rassurer sur les faibles niveaux de radiation auxquels même les professionnels sont exposés sans danger pour leur santé. Le Canada a été et est l'un des meneurs dans l'établissement d'un régime de non-prolifération des armements nucléaires, régime qui continue à être accepté par un nombre grandissant de pays et à être respecté. L'influence de nos diplomates a été rehaussée de façon incommensurable par notre statut de première nation dotée d'un programme bien articulé d'exploitation de l'énergie nucléaire, à des fins pacifiques uniquement. Nous avons aussi mené dans le développement de technologies pour la surveillance de l'utilisation et de l'entreposage de matériaux nucléaires afin de s'assurer de la non-prolifération.

Le Canada est à la fin pointe de la technologie en ce qui concerne la disposition ultime et sûre du combustible nucléaire usé dans les formations rocheuses comme celles qui constituent la majeure partie du Bouclier Canadien. Le programme de gestion du combustible nucléaire usé a été l'objet d'études poussées par un comité consultatif formé d'experts indépendants nommés par les sociétés savantes du Canada, et le concept proposé pour la disposition ultime est maintenant évalué par un forum public.

Le Canada s'est doté d'une des agences de réglementation nucléaire les plus indépendantes, compétentes et considérées au monde. Elle surveille, inspecte, réglemente toutes les activités reliées à la technologie nucléaire au Canada, et accorde les permis.

Opportunités

Alors que nous approchons du vingt-et-unième siècle, nous faisons face à des défis formidables pour permettre à toute l'humanité de jouir d'une qualité de vie acceptable tout en exploitant les ressources de la Terre d'une façon raisonnable et bénigne du point de vue environnemental. Le Canada possède les moyens, tant physiques qu'intellectuels, pour fournir une contribution majeure afin de rencontrer ces défis. Notre technologie nucléaire et notre expertise dans ce domaine sont une partie de ces ressources.

Dimension Nationale

Les réalisations Canadiennes en science et technologie nucléires, et dans la conduite des affaires commerciales dans ce domaine, sont, à juste titre, une source de fierté nationale. Elles n'auraient pas pu être accomplies sans une volonté sur une base nationale et sans la dédication de scientifiques, d'ingénieurs et de techniciens de toutes les parties du Canada et de toutes les cultures. L'industrie nucléaire n'est qu'une des nombreuses dimensions de notre accomplissement en tant que nation. Nous en serions fort diminués dans notre capacité de continuer et de participer à de si grandes entreprises si notre pays était fragmenté.

Plusieurs des composantes majeures du réacteur CANDU, dont la cuve du réacteur elle-même, sont fabriquées dans la province de Québec. Plusieurs des firmes de génie-conseil qui participent ou ont participé aux méga-projets CANDU, ont leur siège social au Québec. Une séparation éventuelle du Québec, en cet environnement de libre-change, pourrait affecter de façon regrettable les partenaires traditionnels au détriment de projets CANDU futurs. Chacun de ces projets génère des commandes de plusieurs millions de dollars pour les entreprises Canadiennes et crée des milliers d'emplois pour plusieurs années pour les travailleurs Canadiens.

La filière CANDU a besoin des ressources et du marché d'une économie domestique de grande taille afin de connaître le succès. L'expérience malheureuse de l'avion Arrow confirme ce fait. Le CANDU a réussi à s'accaparer de 5 % du marché mondial des réacteurs nucléaires, ce qui est un exploit remarquable, compte tenu de la compétition féroce. Cependant, la majorité des réacteurs CANDU a été installée au Canada même. Si notre pays se trouve affaibli, ainsi le sera ce marché. Le Canada a traditionnellement été un fournisseur de matières premières pour l'industrie manufacturière des États-Unis et des autres pays. Le développement du CANDU a contribué à transformer notre pays en un fournisseur de produits manufacturés de haute technologie et de services de génie-conseil.

Il est difficile de concevoir comment notre programme électro-nucléaire aurait pu se développer sans un gouvernement national fort pour promouvoir et supporter la recherche et le développement et pour aider à la mise en marché et au financement de projets tant au Canada qu'à l'étranger. Si l'on parvient à morceler le Canada, ou si le gouvernement fédéral sort de la crise constitutionnelle présente affaibli de façon significative, la capacité de l'industrie nucléaire canadienne en sera certes affectée et amoindrie. On peut se demander à quel point il serait facile de démarrer une nouvelle industrie de haute technologie dans un environnement politique fragmenté.

L'histoire montre que beaucoup de personnes, du Québec notamment, ont contribué au domaine de la science et du génie nucléaires. Elles ont aidé à appliquer cette technologie à la production d'énergie, à la médecine et dans plusieurs autres domaines. L'unité politique et le bilinguisme ont fait la promotion de la communication, de la coopération et du partage du travail, qui ont été et sont encore très importants pour le succès de notre programme électro-nucléaire. Toute séparation politique ne ferait que dresser des barrières à la communication et affaiblir les liens de coopération.

La Société Nucléaire Canadienne a encouragé fortement le bilinguisme et la collaboration entre nos collègues d'un océan à l'autre. Nous croyons que notre programme nucléaire bénéficiera d'un Canada uni avec un gouvernement national fort. Nous comprenons de plus que les Canadiens-Français, qui comptent pour le quart de la population canadienne et qui se trouvent dans toutes les provinces, ont des raisons légitimes de craindre pour la survie de leur culture et de leur langue et de chercher, entre autres, à acquérir un meilleur contrôle des affaires linguistiques et culturelles, ainsi que de leur économie locale. Plusieurs leçons doivent être retenues de l'échec récent des accords du Lac Meech. Ces accords devraient être vus comme l'une des rares occasions dans l'histoire du Canada où toutes les provinces se sont entendues sur un document constitutionnelle ; mais la ratification de ces accords fût rendue impossible à cause de faiblesses dans la procédure d'amendement de la Constitution et de tactiques malheureuses de quelques politiciens qui ont sauté sur l'occasion d'exploiter ces faiblesses pour promouvoir quelques intérâts locaux au détriment de l'unité et de l'harmonie Canadiennes.

C'est maintenant que nos dirigeants se doivent de relever les défis qui affrontent notre pays et d'avoir le courage et l'imagination nécessaires à la création des compromis essentiels à l'établissement de relations de longue durée et bénéfiques à tous entre les provinces. La Société Nucléaire Canadienne, de par sa représentation pan-canadienne, est intéressée à aider à identifier les solutions propices au maintien et au succès de notre pays et de notre industrie nucléaire, lesquels sont tellement interdépendants.

FINAL NOTICE

International Topical Meeting on Advances in Mathematics, Computations and Reactor Physics

to be held April 28 - May 2, 1991
in Pittsburgh, Pennsylvania, USA
(sponsored by ANS, co-sponsored by CNS, ENS and AES Japan)

For information contact CNS office or talk directly to Conference Chairman, J.E. Olhoeft, at (412) 374-5704

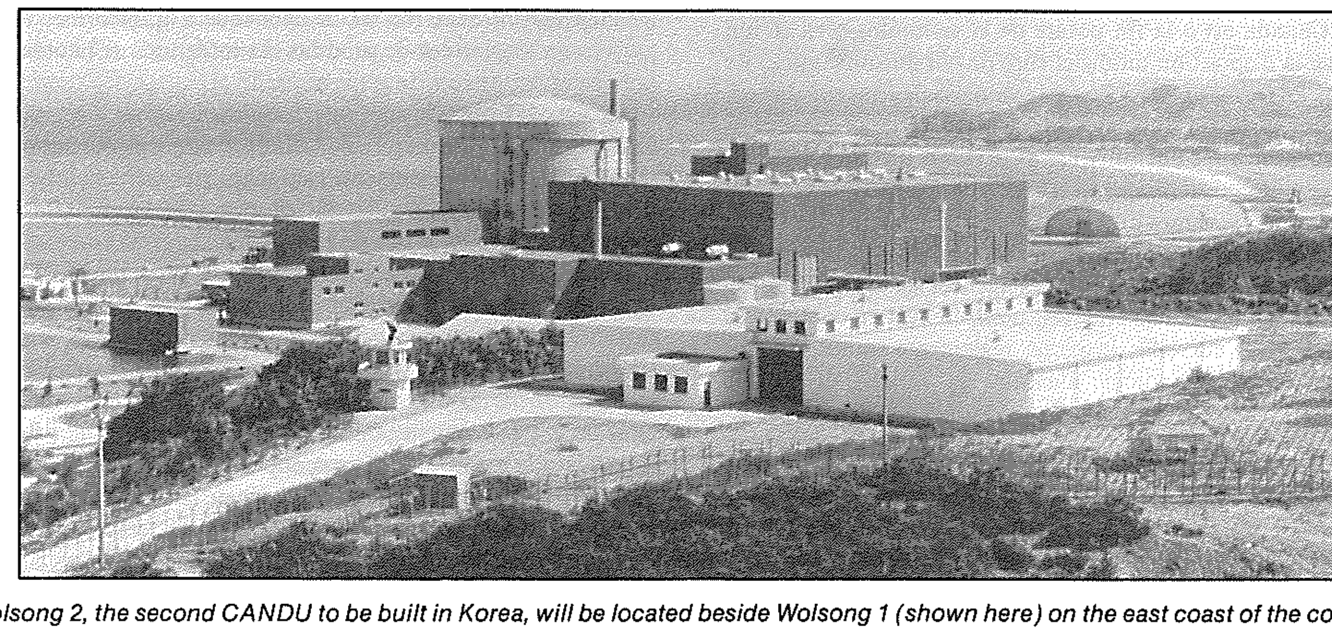
Reminder

The 12th Annual CNS Conference, to be held in conjunction with the 31st Annual Conference of the CNA, will run from June 9 to 12 in Saskatoon, Saskatchewan.

Registration information is being mailed to all members. If you do not receive it or wish more information contact the CNS office, (416) 977-7620.

Clarification

In the last issue of the *Bulletin* there was a table "Breakdown of Whole Body Dose Equivalents by Type of Occupation" which accompanied the article "Dose Limits to be Lowered." This table was not issued by the Atomic Energy Control Board as might be inferred from the article, but by Health and Welfare Canada, Bureau of Radiation and Medical Devices, using data from the National Dose Registry which is run by that bureau.



Wolsong 2, the second CANDU to be built in Korea, will be located beside Wolsong 1 (shown here) on the east coast of the country, south of the city of Ulsan.

Special Paper

The French Nuclear Power Program

Philippe Lemoine, Electricité de France

Ed. Note: *Earlier this year the Toronto Branch had a talk by M. Lemoine which they found interesting and wished to share with all CNS members. Following a suggestion of the Branch chairman, and in the interest of reflecting the bilingual nature of our society the full text of M. Lemoine's talk is presented in both the English and French versions.*

Introduction:

In 1990, nuclear generating stations provided three quarters of France's electricity. With more than 50 operating reactors, France has one of the largest nuclear power programs in the world. The main reasons for this success have been the high level of standardization, the priority given to safety and environmental protection, and an efficient industrial organization.

Background:

Since 1945, despite changes in government, France's energy policy has always had the same objective: generating electricity at the lowest possible cost while maintaining the country's energy independence. This was possible from 1945 to 1955 thanks to the use of domestic coal, followed by a revival of the hydro-electric facilities. Started before the Second World War, the construction of hydro-electric facilities reached its height during the 1950s and was completed for the most part in 1965. At the end of the 60s and until the oil crisis of 1974, oil was widely used due to its very attractive cost. After 1974, in order to improve both the reliability of supply and the balance of trade and still offer the nation inexpensive electricity, the decision was made to begin a vast program to build nuclear generating stations.

With the creation of the French Atomic Energy Commission immediately after the end of the Second World War, France prepared to develop nuclear energy. In 1954, construction of the first three Gas Cooled Reactors (GCR) began at Marcoule. This reactor type, which is entirely French, uses natural uranium as the fuel, graphite as the moderator, and carbon dioxide as the coolant. But it was not until 1963 when Chinon A1 (70 MW) was connected to the grid that France entered into the age of nuclear power.

At the same time, other reactor types were considered: a gas-cooled heavy water reactor was commissioned in 1967; during the same year a 300-MW Pressurized Water Reactor (PWR) was commissioned at Chooz; and in 1973, a 250-MW fast breeder reactor was connected to the grid. From 1963, when the first reactor was built at Chinon, until 1972, five other GCRs were built. But, there were size problems in developing this reactor type and, as a result, costs increased. When in 1974, following the oil crisis, the government decided to begin the vast program that we know today, it chose the Pressurized Water Reactor (PWR), which was tried and tested at the industrial level in the United States.

At the beginning of 1991, France's nuclear generating facilities included 52 PWRs (including Chooz A1), two GCRs (which are to be shut down during the next two years), and two fast breeder reactors (Phénix and Super-Phénix). Six reactors are under construction (three 1,300-MW reactors, and three 1,400-MW reactors).

The standardization policy:

Faced with the size of this nuclear power program, Électricité de France (EDF), which owns and operates the generating stations, and the government decided to design and build a series of standard reactors that would still be adaptable to the various sites. This decision was without precedent outside France.

Standardization is based on the choice of a single technology – the pressurized light-water reactor. To account for the evolution of technical expertise, EDF decided to make periodic improvements by following a policy of a series of standardized reactors.

Thus, the nuclear generating facilities are comprised of three power series: 900 MW, 1,300 MW and 1,400 MW. Within these series, there are various phases characterized by certain types of technology.

The first six 900-MW units (Fessenheim and Bugey) as well as the 18 units of Phase 1 (CP1) are comprised of twin units. They include a reactor building made of prestressed concrete with a leaktight steel liner for containment. The turbine hall is located at a tangent to the reactor building. The turbine is composed of a high-pressure cylinder and three low-pressure cylinders. The 10 units of Phase 2 (CP2) have an identical Nuclear Steam Supply System (NSSS). On the other hand, each unit has its own turbine hall located radially to the reactor building. The turbine is composed of a high-pressure cylinder and two low-pressure cylinders. The 1,300-MW series is characterized by a primary cooling circuit containing four loops (each loop contains a primary coolant pump and a steam generator) while the 900-MW units have only three loops. Through experience, major improvements have been made to the 1,300-MW units, such as the complete autonomy of the units to allow for better operation, a double-walled concrete containment structure, and the physical separation of the safeguard auxiliaries. There are two types of 1,300-MW generating stations; the more recent type benefits from a better optimization of the buildings.

The 1,400-MW series has the distinction of being 100% French, after licensing agreements with American builders expired.

Standardization also helps to reduce construction time and costs. It facilitates the implementation of operational feedback because any modification applies to the entire series. Thus, it is a determining factor in equipment reliability.

Nuclear safety:

In 1970, during the creation of its pressurized water reactor program, France followed the American safety rules. This is why the main safety principles found at EDF are the same as those in use in North America: i.e., a safety analysis combining the barrier containment system (cladding, primary cooling system, containment structure) and defence-in-depth (quality assurance is applied to each barrier from design until start up).

If the quality of the facilities is essential for minimizing the risks of incidents, the quality of the operators is just as important. This is why EDF has set up a powerful training structure for all levels of personnel; there are training periods at EDF's special schools, with the manufacturer, or on site, as well as simulator training, computer-aided training, etc.

Simulator training is especially interesting since it places the operators in realistic conditions and prepares them to confront incidents or even serious accidents. Team behaviour can be observed and interpersonal problems can be studied (cohesion of the team, type of errors made, psychology). Here again, standardization plays an important role since a single type of simulator can be used for a large number of identical generating stations. An operator transferred from one generating station to another does not feel disorientated, and needs only a small amount of time to adapt. In fact, any adaptation is more on the human rather than the technical level.

Finally, France has paid special attention to accident procedures. Even if many procedures have been created and improved over the years covering even the most unlikely accidents, it has seemed necessary to go further. As a result, EDF is presently in the process of setting up a new approach to on-line safety in the generating stations: the physical states approach. The traditional approach of searching for the event that initiated an incident contains several drawbacks: the possibility of a diagnostic error, problems during multiple failures (as at Three Mile Island), or unforeseen incidents. The physical states approach is not an investigation into the cause of an incident but rather a diagnosis of the physical state of its reactor. On the basis of this, a procedure tells the operator how to return to a safe state.

Environmental protection:

Protecting people and the environment against radiation is a major concern right from the selection of the site to the operation of the generating station. The effect of thermal, chemical, and radioactive discharges into the sea, rivers, or the air is the subject of several studies using scale models or computer models. Special attention is paid to the richness and sensitivity of the aquatic environment. One year before starting up the generating station, a "radiological zero point" is established in order to monitor the impact of the generating station over time.

As far as the architecture of the generating stations is concerned, famed architects have been assigned the task of carrying out studies to integrate the generating stations into their natural surroundings.

By reducing the use of fossil-fuel generating stations, nuclear energy in France has indirectly led to a large reduction of the acid gas and other emissions that contribute to the greenhouse effect. In 1980 sulphur dioxide (SO_2) emissions reached almost one million tonnes; in 1987 they were lower than 85,000 tonnes.

This constant concern for the environment is an important factor in the acceptance of the nuclear program by the French public, especially around the sites. But this acceptance is also the result of major efforts made by EDF to provide the public with a great deal of information by distributing information brochures, arranging tours of the generating stations, and participating in numerous expositions.

The social and economic impact of a generating station is also a very favourable factor. The many projects (roadways, housing, schools . . .) that are necessary during the construction period benefit the entire region. Professional training programs encourage the use of local workers, and they may account for 40 to 50% of the employees on the site.

The participants in the French nuclear power program:

In addition to being the owner and operator of its generating facilities, EDF fills the role of project manager and architect-engineer. In this function, it defines the scope of the project, the general rules, and the technical specifications that all the participants must follow. It prepares and signs the contracts for equipment and civil-engineering projects that are passed on to various partners and builders for study, off-site construction, assembly and testing. It coordinates and defines the assembly and subassembly work and ensures cooperation and communication between the other participants. It demonstrates to the safety authorities that the facilities meet the regulations in force.

The French nuclear industry is organized around two poles: the builders and the Atomic Energy Commission (CEA). The standardization policy, the selection of a single technology, and the importance of the task, quickly led to grouping the main builders for maximum efficiency. Therefore, Framatome is the sole supplier of Nuclear Steam Supply Systems. Framatome designs and builds the main components: reactor vessel, boilers, pressurizer, and in-core instrumentation. It ensures the transportation and assembly of materials, manufactures fuel, and participates in testing and commissioning.

Today, a single group builds turbo-generator sets for French generating stations – GEC Alsthom.

Finally, more than 600 diverse, major companies are also involved in carrying out France's nuclear power program.

When it was created at the end of the Second World War, CEA was primarily a nuclear research organization. It now includes several industrial and commercial branches. The largest, Cogema, provides all services related to the fuel cycle. Besides its involvement in mining (Cogema produces 80 % of all the uranium extracted from French soil and has several foreign investments, notably in Canada), Cogema is involved in the conversion of ore to metal and uranium hexafluoride through the Comurhex company (Cogema 49%, Péchiney 51%). The uranium is enriched in the Eurodif factory at Tricastin, which was built with major investments from Cogema (51.3%) and investments from other countries (Italy, Spain, Belgium). Irradiated fuel is reprocessed in factories at the Hague and Marcoule. Finally, the management and storage of radioactive waste is the responsibility of the National Agency for Radioactive Waste Management (ANDRA).

Conclusion:

With nuclear power accounting for 75% of the electricity generated, the economic optimum has been reached and the French nuclear power program is considered to be complete. The rate of construction should stabilize at one unit every two or three years in order to meet increases in the demand for electricity. But, future replacement of the generating facilities must be taken into consideration. It is with this in mind that France continues its research on the light water reactor for the year 2000 (spectral shift reactors and / or under-moderated reactors) and continues to develop fast breeder reactors with its European partners.

Fifteen years after introducing its nuclear energy program, France has won its bet. The rate of energy dependence has dropped from 77% in 1973 to about 47% in 1990. The availability of the nuclear generating stations is most satisfactory (more than 76% for all 900-MW units in 1990). It is higher than the initial predictions, which allows EDF to sell surplus electricity to its European neighbours at very competitive prices. Thanks to nuclear energy, the people of France enjoy one of the most inexpensive electricity rates in Europe.

These results show the mastery and competence acquired by EDF and its industrial partners in the nuclear field. Its experience gives it an expertise that places it in the forefront of electric utilities and allows it to assist foreign countries interested in developing nuclear power.

Le programme nucléaire français

Philippe Lemoine, électricité de France

Introduction :

En 1990, les centrales nucléaires françaises ont fourni les trois quarts de la production national d'électricité. Avec plus de 50 réacteurs en service, la France possède un des plus importants programmes nucléaires dans le monde. Les principales clés de cette réussite sont le haut niveau de standardisation, la priorité donnée à la sûreté et à la protection de l'environnement, une organisation industrielle efficace.

Historique :

Depuis 1945, en dépit des changements de gouvernement, la politique énergétique française a toujours été tournée vers le même objectif, la production d'électricité à moindre coût tout en préservant au maximum l'indépendence du pays vis-à-vis de l'extérieur. Cela a pu être réalisé de 1945 à 1955 grâce à l'utilisation du charbon domestique, puis par la relance de l'équipement hydro-électrique dont la construction avait été amorcée avant-guerre mais qui a connu son plein développement dans les années 50. Ce programme s'est pratiquement achevé en 1965. À la fin des années 60 et jusqu'à la crise pétrolière de 1974, l'utilisation du huile s'est largement développé afin de bénéficier du coût très attractif de ce combustible. Après 1974, pour améliorer à la fois la sécurité d'approvisionnement et l'équilibre de la balance commerciale tout en mettant à la disposition de la nation une électricité bon marché, il a été décidé de lancer un vaste programme de construction de centrales nucléaires.

Dès la fin la guerre, avec la création du Commissariat à l'Énergie Atomique, la France se dote de moyens pour développer l'énergie nucléaire. En 1954, débute à Marcoule la construction des trois premiers réacteurs de type UNGG. Cette filière, entièrement française, utilise l'uranium naturel comme combustible, le graphite comme modérateur et le gaz carbonique comme fluide caloporteur. Mais ce n'est véritablement qu'en 1963 avec le couplage Chinon A1 (70 MW) que la France entre dans l'ère de l'électricité nucléaire.

Parallèlement, des tentatives sont faites pour explorer d'autres filières : un réacteur à eau lourde refroidi au gaz est mis en service en 1967; la même année un réacteur à eau sous pression de 300 MW est mis en service à Chooz et en 1973 un surgénérateur de 250 MW est couplé au réseau. Après le premier réacteur de Chinon, cinq autres UNGG suivront jusqu'en 1972. Mais le développement de cette filière se heurte à des problèmes de taille et donc de coûts. Aussi quand en 1974, à la suite de la crise pétrolière, le gouvernement décide de lancer le vaste programme que nous connaissons actuellement, le choix se portera sur la filière des réacteurs à eau sous pression (REP), qui avait fait ses preuves sur le plan industriel aux États-Unis.

Au début de 1991, le parc nucléaire français se compose de 52 réacteurs REP (dont Chooz A1), deux unités UNGG (qui devraient être arrêter dans les deux prochaines années), et deux surgénérateurs : Phénix et Super-Phénix. Il y a en construction 6 réacteurs (3 de 1300 MW et 3 de 1400 MW.

La politique de standardisation :

Devant l'importance de ce programme nucléaire, Électricité de France (EDF), propriétaire et exploitant des centrales, et les pouvoirs publics ont fait le choix sans équivalent à l'étranger de concevoir des produits standards, fabriqués en séries mais adaptables aux différents sites.

La standardisation repose sur le choix d'une seule technologie, les réacteurs à eau légère sous pression. Pour prendre en compte l'évolution du savoir-faire, EDF a choisi d'introduire améliorations et perfectionnements de façon discontinue, au travers d'une politique de paliers technologiques successifs.

C'est ainsi que le parc de centrales nucléaires est constitué de 3 paliers de puissance, les centrales de 900 MW, 1300 MW et 1400 MW. À l'intérieur de ces paliers, on trouvera différentes séries caractérisées par certains choix technologiques.

Les 6 premières tranches de 900 MW (Fessenheim et Bugey) ainsi que les 18 tranches suivantes du premier contrat de programme (CP1) sont constituées de tranches jumelées. Elles comprennent un bâtiment réacteur avec enceinte en béton précontraint doublée d'une peau métallique d'étanchéité. La salle des machines est disposée tangentiellement au bâtiment réacteur.

La turbine est constituée d'un corps haute pression et de trois corps basse pression. Les 10 tranches suivantes du deuxième contrat de programme (CP2) sont dotées d'un îlot nucléaire identique. En revanche chaque tranche dispose en propre d'une salle des machines disposée radialement au bâtiment réacteur. La turbine est constituée d'un corps haute pression et de deux corps basse pression.

Le palier 1300 MW se caractérise par un circuit primaire de 4 bouches (comprenant chacune une pompe primaire et un générateur de vapeur) alors qu'il n'y en avait que 3 pour les unités de 900 MW. Mais l'expérience acquise a aussi permis d'apporter des perfectionnements notables aux tranches de 1300 MW. Citons entre autre l'autonomie complète des tranches permettant une meilleure exploitation, une enceinte de confinement à double paroi en béton, la séparation physique des auxiliaires de sauvegarde. Il existe deux types de centrales de 1300 MW, les plus récentes bénéficiant d'une meilleure optimisation des bâtiments.

Le palier 1400 MW a la particularité d'être 100 % français suite à la fin des accords de license conclus avec les constructeurs américains.

La standardisation contribue aussi à réduire les délais et les coûts. Elle facilite la mise en oeuvre du retour d'expérience car toute modification qui en résulte s'applique à l'ensemble du palier. Elle est ainsi un facteur déterminant de la fiabilité des équipements.

La sûreté nucléaire :

En 1970, lors de la conception de son programme de réacteurs à eau sous pression, la France s'est appuyé sur les règles de sûreté américaines. C'est pourquoi nous retrouvons les mêmes grands principes que ceux en usage en Amérique du Nord à savoir une analyse de sûreté associant la méthode des barrières (gaine du combustible, circuit primaire, enceinte de containment) et la défense en profondeur (pour chaque barrière application des méthodes d'"assurance de la qualité", de la conception à la mise en service).

Si la qualité des installations est primordiale pour minimiser les risques d'incidents, la qualité des hommes qui exploitent ces installations a au moins autant d'importance. C'est pourquoi EDF a mis en place une puissante structure de formation de son personnel à tous les niveaux : stages dans les écoles spécialisées d'EDF, chez les constructeurs ou sur les chantiers, entraînement sur simulateur, enseignement assisté par ordinateur...

La formation sur simulateur occupe une place privilégiée en mettant les opérateurs dans des conditions réalistes et les prépare à faire face à des incidents ou même des accidents graves. On peut alors observer le comportement de l'équipe et étudier les problèmes qui se posent sur le plan humain (cohésion de l'équipe, nature des erreurs commises, psychologie), Là encore, la standardisation joue un rôle important puisque les simulateurs nécessaires peuvent être d'un seul type pour un grand nombre de centrales identiques. Un opérateur transféré d'une centrale à une autre n'est nullement dérouté et le temps nécessaire à son adaptation est réduit au strict minimum : c'est beaucoup plus une adaptation au milieu humain qu'à la technique.

Enfin, la France a accordé une attention toute particulièrement aux procédures ont été élaborées et améliorées aux cours des ans pour essayer de couvrir les accidents même les plus improbables, il a cependant paru utile d'aller plus loin. C'est ainsi qu'est en train de se mettre en place actuellement dans les centrales nucléaires françaises une nouvelle approche de la sûreté en exploitation : l'approche par états généralisés (APE). La démarche classique qui consiste à rechercher l'événement initiateur d'un incident présentait plusieurs inconvénients : possibilité d'erreur de diagnostic, difficultés lors de pannes multiples (comme à TMI) ou d'incidents non prévus. L'approche par états demande non pas de déceler la cause d'un incident, mais d'établir un diagnostic de l'état physique du réacteur. À partir de là, une procédure indique à l'opérateur comment revenir à une situation sûre.

La protection de l'environnement :

La protection des populations et de l'environnement contre les radiations est une préoccupation majeure dès le choix d'un site jusqu'à l'exploitation de la centrale. L'impact des rejets thermiques, chimiques et radioactifs en mer, en rivière ou dans l'atmosphère fait l'objet de nombreuses études sur maquettes ou directement sur le site, en liaison avec des modèles mathématiques. Une attention particulière est portée à la richesse et à la sensibilité du milieu aquatique. Un an avant de démarrage de la centrale, on établit un "point zéro radiologique" afin de pouvoir suivre l'impact de la centrale au cours du temps.

Sur le plan architectural, les études d'insertion des centrales dans le paysage, confiées à de célèbres architectes, ont pour objectif d'intégrer les bâtiments dans leur environnement naturel.

Le développement de l'énergie nucléaire en France a conduit indirectement à une réduction importante des émissions acides et gaz à effet de serre à cause de l'utilisation de plus en plus marginale des centrales thermiques classiques. C'est ainsi qu'en 1980 les émissions d'anhydride sulfureux (SO_2) atteignaient presque un million de tonnes; en 1987 elles ont été inférieures à 85 000 tonnes.

Ce souci constant de protéger l'environnement est un facteur important qui favorise la bonne acceptation du programme nucléaire dans le public français, spécialement autour des sites. Mais ce résultat est également le fruit d'efforts importants faits par EDF pour fournir au public une large information à travers la diffusion de documents adaptés au niveau de chacun, l'ouverture des centrales aux visiteurs et la participation à des nombreuses expositions.

Enfin l'impact socio-économique d'une centrale est également un élément très favorable. De nombreux aménagements (voirie, logements, écoles...) nécessaires pendant la période de construction vont bénéficier par la suite à toute la région. Le recours à l'emploi régional est favorisé par des actions de formation professionnelle et peut atteindre 40 à 50 % des effectifs du chantier.

Les acteurs du programme nucléaire français :

Outre son rôle du propriétaire et d'exploitant de ses équipements de production, Électricité de France assure elle-même le rôle de directeur de projet et d'architecte-industriel. À ce titre, elle définit l'ensemble du projet, les règles générales et les spécifications techniques à observer par tous les intervenants. Elle prépare et signe les contrats qui sont passés aux différents partenaires et constructeurs pour l'étude, la construction en usine, le montage et les essais des équipements et ouvrages de génie civil. Elle coordonne la définition des ensembles et sous-ensembles et assure interfaces et cohérence entre les autres intervenants. Elle répond devant les autorités de sûreté de la conformité des installations avec les règles en vigueur.

L'industrie nucléaire française s'organise autour de deux pôles, les constructeurs et le Commissariat à l'Énergie Atomique (CEA).

La politique de standardisation du programme français, le choix d'une technologie unique et l'importance de la tâche ont conduit très vite à regrouper les principaux constructeurs pour une efficacité optimum. C'est ainsi que Framatome est le seul fournisseur des chaudières nucléaires. Il en conçoit et construit les principaux éléments : cuve, générateurs de vapeur, pressuriseur et instrumentation du coeur. Il assure le transport et le montage des matériels, la fabrication du combustible et participe aux essais et aux mises en service.

La construction des groupes turbo-alternateurs des centrales françaises est aujourd'hui confiée au seul groupe GEC Alsthom.

Enfin plus de 600 enterprises de taille très diverses sont également impliquées dans la réalisation du programme nucléaire français.

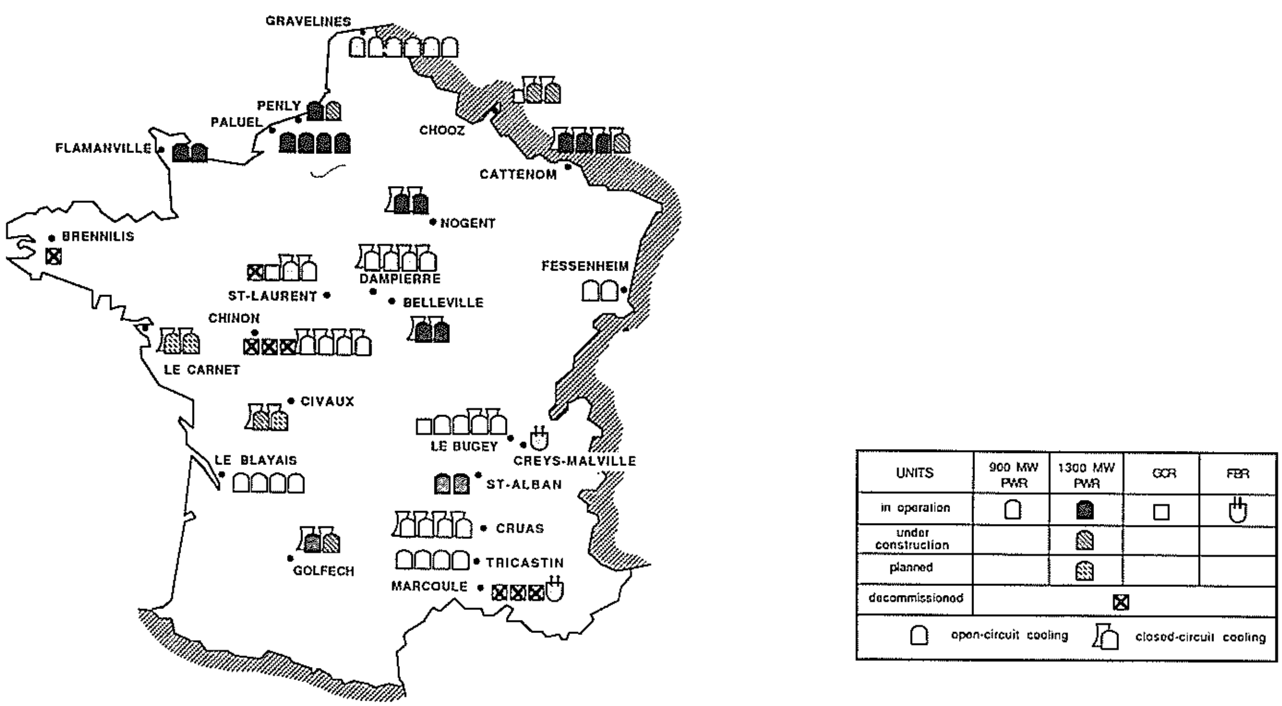
Créé à la fin de la seconde guerre mondiale, le CEA était avant tout un organisme de recherche sur le nucléaire. Il compte aujourd'hui de nombreuses filiales à vocation industrielle et commerciale. La plus importante, Cogema, fournit l'ensemble des services liés au cycle du combustible. Outre son activité minière (elle produit 80 % de l'uranium extrait du sol français et possède de nombreuses participations à l'étranger, notamment au Canada), Cogema est impliquée dans la conversion du minerai sous forme de métal et d'héxafluorure d'uranium par l'intermédiaire de la Comurhex company (Cogema 49 %, Péchiney 51 %). L'enrichissement de l'uranium est effectué dans l'usine Eurodif du Tricastin construite avec la participation principale de Cogema (51,3 %) et celle de pays étrangers (Italie, Espagne, Belgique). Le retraitement des combustibles irradiés se fait dans les usines de La Hague et de de Marcoule. Enfin, la gestion et le stockage des déchets est sous la responsabilité de l'Agence National pour la gestion des Déchets RAdioactifs (ANDRA).

Conclusion :

Avec 75 % d'électricité d'origine nucléaire, l'optimum économique est atteint et l'on peut considérer que le programme nucléaire français est achevé. Le rythme de construction devrait se stabiliser à une tranche tous les deux ou trois ans afin de suivre la progression de la demande en électricité. Mais il faut penser au remplacement futur du parc. C'est dans cet esprit que la France poursuit ses recherches pour définir le réacteur à eau légère de l'an 2000 (réacteur à variation de spectre et/ou sous-modéré) et avec ses partenaires européens continue le développement des surgénérateurs.

Quinze ans après le lancement du programme électronucléaire, la France a gagné son pari. Le taux de dépendance énergétique est passé de 77 % en 1973 à environ 47 % en 1990. La disponibilité du parc de production nucléaire est très satisfaisante (plus que 76 % pour l'ensemble des tranches 900 MW en 1990). Elle est supérieure aux prévisions initiales, ce qui permet à EDF de faire profiter ses voisins européens de son excédent de production, et ce à un prix très compétitif. En effet, grâce au nucléaire, la France bénéficie d'une des électricités les moins chères d'Europe.

Ces résultats démontrent la maîtrise et la compétence acquises par EDF et par ses partenaires industriels dans le domaine nucléaire. Son expérience lui confère un savoir-faire qui la situe au tout premier rang des producteurs d'électricité et lui permet d'apporter son assistance aux pays étrangers soucieux de développer l'énergie électronucléaire.



Best Undergraduate Paper

An Ultrasonic System for the Monitoring of Two-phase Flow Parameters in a Nuclear Power Plant Primary Heat Transport System

Bep L.G. Verberk
Department of Electrical and Computer Engineering, McMaster University

***Ed Note:** Each year, for over a decade, the CNS, together with the CNA, has held a conference especially for the presentation of nuclear-related technical papers by students of Canadian universities. This year the conference was held at the Royal Military College, in Kingston, Ontario on Friday and Saturday, March 22, 23, 1991.*

Michelle DeSa, an officer cadet at RMC, was the student Chairperson of this very well-run conference, ably assisted by fellow RMC'ers Memphis Don and Eric Daoust. RMC professors Hugues Bonin (CNS president), Les Bennett, Brent Lewis and William Lewis served as staff advisors.

The 26 papers presented were placed in two categories for judging – undergraduate and graduate. In each group the quality of the papers and of the presentations was universally high, making the task of the judges difficult.

In the undergraduate category Bep Verberk, a fourth year student in the Department of Electrical and Computer Engineering at McMaster University took the top honours for his paper, "An Ultrasonic System for the Monitoring of Two-Phase Flow Parameters in a Nuclear Power Plant Primary Heat Transport System." We are pleased to be able to publish his paper in this issue of the Bulletin.

The graduate section was won by Anne Hardman, a PhD candidate at Queen's University, for a paper on "Fission Product Release in Slowpoke Reactors." Her research work is being conducted on the Slowpoke reactor at RMC under Dr. Brent Lewis. We hope to publish her paper in the next issue.

Abstract:

An ultrasonic instrumentation system has previously been developed for monitoring gas-liquid two-phase flow parameters.[1,2] By designing an appropriate interface this system has been adopted for use with an IBM compatible computer. The interface design allows for the collection of data from two separate ultrasonic transducers.

The system uses a pulse-echo technique to determine the location of a gas-liquid interface by measuring the round trip flight time of a pulse reflected by the interface. The flight times of several pulses provide information on the transient interfacial geometry. Once collected by the computer this information can be analyzed with specialized software to determine film thickness, void fraction, and flow regime.

The potential for determination of other interfacial parameters important to the analysis of Nuclear Power Plant Primary Heat Transport systems also exists.

Introduction:

The study of two-phase flow is important to the nuclear industry for the design of primary coolant loops and secondary loops. For CANDU type reactors the coolant in the primary loop is kept under enough pressure to maintain single phase. The primary coolant is used to heat water in a secondary loop. The water in the secondary loop is allowed to boil, producing vapour to drive a steam turbine. The design of the secondary loop requires an understanding of two-phase flow phenomena. However, flow study is also important in regard to the primary coolant loop. If a pressure drop occurs, or there is a pump failure, void may begin to develop in the primary loop. An understanding of two-phase flow is necessary in order to assess the implications of this situation. The safe operation of water cooled reactors is therefore dependent on understanding two-phase flow.[3]

Parameters of interest in two-phase flow study include void fraction, interfacial area, flow regime, film thickness, and flow velocity. Each of these parameters has a direct influence on the pressure drop and heat transfer characteristics of the flow. Pressure drop and heat transfer are two flow characteristics which are needed to accurately model two-phase flow systems.

Theory:

A sound wave consists of the transportation of energy and momentum by means of a disturbance in the medium through which it propagates. In order for sound to propagate the medium must possess elastic properties.[4]

The key property of sound waves which makes them applicable to non-destructive testing, and non-intrusive measurement, is reflection. When an incident sound wave encounters an interface between two separate mediums a portion of the incident wave tends to be reflected back through the first medium, while a portion of the incident wave tends to be transmitted through the second medium.

The proportions of the sound wave which are reflected and transmitted are given by the reflection and transmission coefficients, R and T respectively. R and T depend on the densities (p) and the speeds of sound (c) for the two mediums as shown in the following equations:

$$R = \frac{I_r}{I_i} = \left[\frac{p_2c_2 - p_1c_1}{p_2c_2 + p_1c_1}\right]^2 \quad (1)$$

$$T = \frac{I_t}{I_i} = \frac{4p_1c_1p_2c_2}{(p_1c_1 + p_2c_2)^2} \quad (2)$$

where I_i, I_r, and I_t represent the intensities of the incident, reflected, and transmitted waves respectively. The product of density (p) and speed of sound (c) for a medium is known as the characteristic impedance of the medium. As can be seen from the equations a large difference in characteristic impedances for two materials will cause a large portion of the incident wave to be reflected.

The reflection coefficient for a gas-water interface is 0.99. This is the property of sound waves which enables us to apply ultrasonic techniques to the measurement of various two-phase gas-liquid flow parameters.

The Ultrasonic System:

The Ultrasonic System makes use of a commercial ultrasonic analyzer (Panametrics Model 5052UA) and transducer to generate the ultrasonic incident pulses and receive the ultrasonic echo pulses.

Custom hardware was designed to collect round trip flight times for 1024 ultrasonic pulses. A block diagram of the system appears in Figure 1. When the Panametrics 5052UA generates an ultrasonic pulse, a counter in the custom hardware is started. The counter increments at a rate of 10 MHz. When an echo is detected by the transducer the *pulse converter* converts this signal into a digital pulse. The digital pulse is used to shut off the counter, and store the count value in local memory. After storing the round trip flight time counts for 1024 pulses the custom hardware discontinues the data collection process.

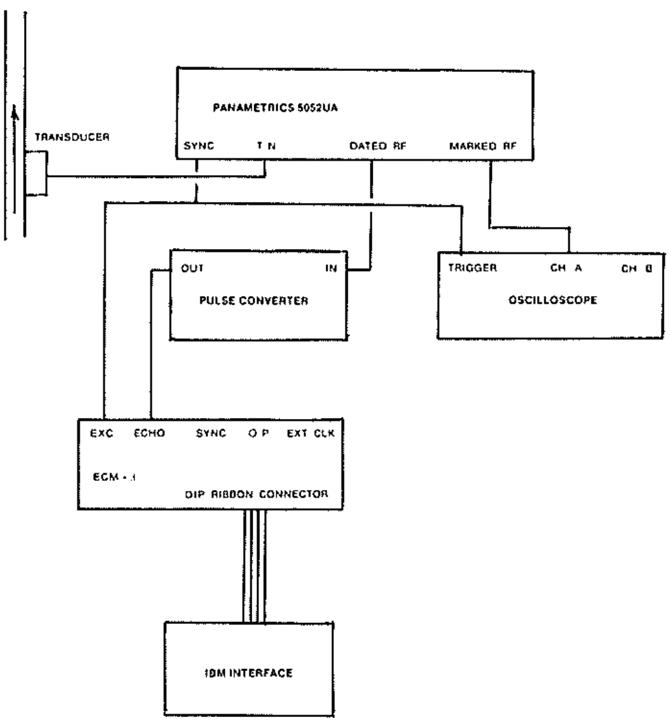


Figure 1. Ultrasonic System block diagram

An interface board which allows the Ultrasonic System to transfer data to an IBM XT/AT compatible computer was designed, constructed, and tested.

The interface board is operated with software, which was also developed. The interface board is accessed via the software using four port addresses in the PC's I/O address space. The first two addresses can be used to access data from the Ultrasonic System (currently only one is being used). The third address is used to send control information from the computer to the Ultrasonic System. The final address is used to initialize the interface board.

Experiments:

An experiment was conducted using the set-up shown in Figure 2.[5] For this experiment, air and water at known flow rates are caused to flow through a 2.0 cm I.D. horizontal pipe. The test section was made of aluminum to demonstrate the feasibility of this technique with metal pipe materials. The remainder of the horizontal section was made of glass to allow visual observation of the flow.

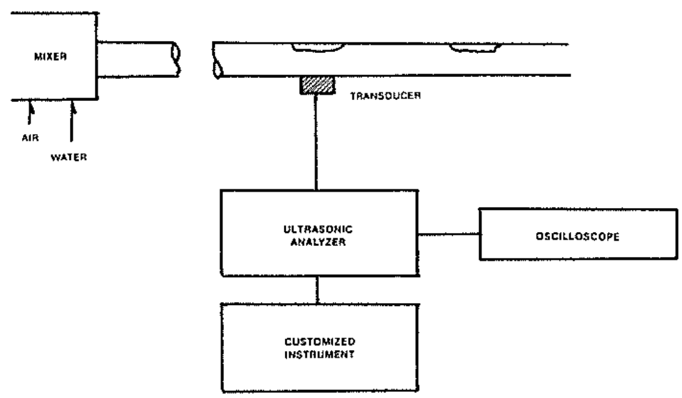


Figure 2. Experimental set-up for horizontal flow regime determination

This experiment allowed the examination of horizontal flow regimes, such as stratified smooth, stratified wavy, plug, and slug flow. The pictorial plots for these results provide a very accurate visualization of the flow regime.

In addition to providing a visualization of the flow regime, the computer can be used to analyze the data to determine various two-phase flow parameters, such as void fraction and film thickness.

In the horizontal pipe flow experiment the time-averaged void fraction, Σg, is calculated using the 1024 instantaneous liquid level measurements over time period of ten seconds. That is,

$$\Sigma_g = \frac{1}{1024} \sum_{i=1}^{1024} \left(1 - \frac{A_i}{A}\right) \qquad (3)$$

where: A is the cross-sectional area of the pipe, and A_i is the cross-sectional area of the water filled portion of the pipe.

Experiments are currently being conducted on the test apparatus shown in Figure 3. This apparatus is used to examine the phenomena of natural circulation. Air is allowed to enter the system at the bottom of the test section. The natural buoyancy of the air causes it to rise in the test section. This has the effect of inducing a natural circular flow in the system with water rising in the test section and falling in the downcomer. It

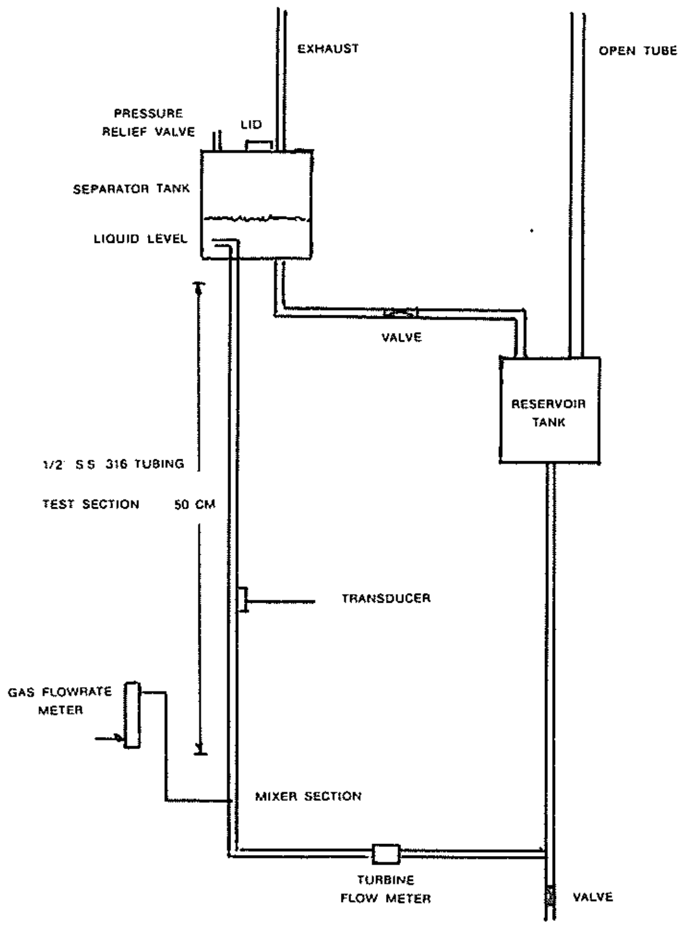


Figure 3. Experimental set-up for natural circulation loop

is hoped that the Ultrasonic System can be used to distinguish the prevalent flow regime, determine the film thickness, and determine the void fraction for various air flow rates.

Conclusion:

It has been shown that ultrasonic techniques can be used to monitor two-phase flows, and applied to the determination of two-phase flow parameters.

With the adoption of the Ultrasonic System for use with IBM compatible computers comes an increase in processing capabilities. It is foreseeable to have the computer collect and display the information being gathered by the Ultrasonics System in a real-time manner, allowing the user to view a scrolling picture of the flow on the computer screen.

The current Ultrasonic System, with only one transducer, presents two limitations which will be addressed by the additional capability of collecting data from two separate transducers. First of all, annular flow is currently indistinguishable from a low level stratified flow in a horizontal pipe. With two transducers, one below the pipe, and one above, annular flow will be distinguishable by the upper transducer detecting a film thickness. In stratified flow the upper transducer will not detect a gas-liquid interface. Secondly, the flow velocity cannot currently be determined. A second transducer could be placed at a known distance further along the test section. The time for similar flow features to pass from the first transducer to the second transducer could be measured. From this information the flow velocity could be determined. This procedure would be limited to stable flow regimes with easily recognizable features, such as plug, or slug flow.

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CNS Nuclear Simulation Symposium

The 16th annual Simulation Symposium sponsored by the Nuclear Science and Engineering Division will be held August 26 & 27, 1991 at Saint John, New Brunswick.

For information contact:

Paul Thompson, Point Lepreau NGS,
(506) 659-2220,
or the CNS office.

International Topical Meeting on Safety of Thermal Reactors

This meeting, sponsored by the American Nuclear Society and co-sponsored by the CNS, will be held July 21 to 25, 1991 in Portland, Oregon.

For information contact:

Allen Brown, Ontario Hydro,
(416) 592-4535.

Collapse of an Industry: Nuclear Power and the Contradictions of U.S. Policy

John L. Campbell, Cornell University Press, New York (1988), ISBN 0-8014-9500-8

Reviewed by Ric Fluke

John Campbell, a professor of Sociology at the University of Wisconsin – Parkside, examines the commercial nuclear power industry in the United States in the context of modern capitalist democracies. He advocates a political system that is combinative of institutionalism and neo-Marxism. The book is heavy reading, with perhaps too much multi-syllabic jargon. Despite this, *Collapse of an Industry* offers a well organised account of the downfall of the U.S. nuclear industry. It is elaborately presented, with plenty of footnotes and bibliographical references.

Campbell cites four factors that contributed to the industry's decline: (a) a failure to standardise equipment and rationalise competition; (b) growing public concern about safety and waste disposal; (c) an economic crisis; and, (d) contradictions in the complex political and regulatory institutions. His thesis stresses the latter. He argues that institutional inconsistencies prevented the long term planning necessary for the survival of the nuclear industry, or indeed, any competitive industry based on a high risk, capital intensive and complex technology that requires a long lead time.

To defend his thesis, Campbell examines the effects of institutional frameworks on processes for policy making and long term planning, by comparing the nuclear industry in the U.S. with those in France, Sweden and West Germany. (However, his Wisconsin sights fell short of the land of moose, Molson, oatmeal and CANDU). Since the nuclear industry is not unique in its high cost, high risk, technological complexity and long lead time, Campbell also examines two other U.S. industries having similar traits, namely, aircraft and pharmaceuticals. Below is a brief summary of his case studies.

In France, all segments of the nuclear industry are nationalised and centralised including manufacturing, utility, and policy making. The important aspect about policy making, argues Campbell, is that it is closed (no access by "public interest" groups), made up of an elite few from industry and government, including the finance ministry who administer the capital. Anti-nuclear activism in France is well known, as in most other countries, but there is no framework or mechanism for intervention in either policy making or policy implementation. Campbell concludes that, because this system of institutions provided the necessary framework for long term planning, then reactor design could be standardised to control costs for an assured market with government administered finance, guided by an elite group of incoercible policy makers.

In Sweden, the sole and centralised manufacturer offered a standard BWR, but the decentralised free market utilities ordered larger non-standard reactors and also purchased PWR's from Westinghouse; this contributed to their financial crisis. Campbell describes policy making in the Swedish socialist state as "open"; this provided the available institutional devices for citizens to effect change in nuclear policy. Campbell argues that the Swedish nuclear industry collapsed because of such institutional fragmentation which compromised long term planning.

In West Germany, where a sole architect-engineering organisation was created to standardise design, utilities purchased both BWR's and PWR's of larger non-standard designs. Furthermore, the latest safety improvements were retro-fitted into the plant. These factors contributed to financial crisis. Policy making is described as centralised and "closed," but policy implementation is decentralised, fragmented, and open to public intervention. Thus, anti-nuclear groups have an institutional mechanism to intervene, as in the U.S.. Campbell notes that the Green Party began as a forum to effect changes in the making of, rather than the implementing of nuclear policy. Although they have not gained enough support in the coalitionist government, it would appear none the less that the end result in West Germany is similar to that in Sweden.

The aircraft and pharmaceutical industries are similar to nuclear in their high cost, high risk, technological complexity and long lead time; also, they are highly competitive. The differences, notes Campbell, are the institutional structures, including financial management and policy making.

The high cost of testing and development for the aircraft industry is largely financed by the military, and investments by pharmaceutical firms for testing of new drugs are protected by patent laws guaranteeing exclusive marketing rights and high consumer prices. Also noted is that the airlines which purchase aircraft can recover their costs through regulated air fares. Therefore, the institutional framework for financial management allows both industries to carry out the necessary long range planning. To remain competitive, however, some aircraft safety faults did not receive adequate attention, such as the DC-10 design problem; this, Campbell argues, was because policy making is by an elite few in the FAA who are not coerced by activist groups.

In the pharmaceutical industry, as Campbell points out, the pressures of competition and profit led to some shortfalls in long term testing; some of the consequences of insufficient testing were severe, such as the tragedies that resulted from use of thalidomide. Because of political pressures, policy making was opened to the public and more stringent testing requirements and regulations were imposed. The result has been fewer new drug innovations because, as Campbell concludes, long term planning was compromised when policy making was "opened" to public intervention. With the aircraft industry, however, long term planning is facilitated by government financial commitment, air fare regulation and "closed" policy making by an elite.

By examining case studies in detail, in the context of the institutional frameworks, Campbell makes his case that modern democracy and a free market are incompatible institutions for the survival of a high risk, capital intensive and technologically complex industrial sector such as commercial nuclear power. Long term planning can not be facilitated in such a framework. Without long term planning, there is a lack of standardisation, lack of financial management and a lack of centralised policy making and implementation.

The aftermaths of TMI and Chernobyl affected public opinion and further fuelled anti-nuclear activism. But this, argues Campbell, was not a particularly important factor; rather, the important factor was open policy implementation. (Advocacy groups can influence public opinion and thereby persuade local governments to intervene "in the public interest," for the ever-creditable purpose of "evaluation and review.") The key point is not whether there is anti-nuclear sentiment because there always will be; rather, it is whether or not a mechanism exists within the institutional framework to intervene or effect changes in nuclear policy).

This book is required reading for those involved in long term planning for the nuclear industry, and I would highly recommend it to anyone interested in analyzing industries characterised by high risk, high cost and high tech, within existing or proposed politico-economic institutions. Even though it assesses the situation in the U.S., the thesis is broadly applicable, and it can help to identify and evaluate considerations for long term planning for the Canadian nuclear power programme.

Nuclear Power Development: Prospects in the 1990s

Stanley M. Nealey, Battelle Press, Columbus, Ohio (1990), ISBN 0-935470-53-0

Reviewed by Ric Fluke

Despite a decade of stagnation in U.S. nuclear power development, the industry has by no means been asleep. Major manufacturers have been working with utilities and the Electric Power Research Institute to develop "Next Generation" reactors that are safer and more economic. These range from improvements to existing designs to new, inherently safe reactors with passive heat removal.

Although utilities are not exactly jumping forth to place orders, there would appear to be a renewed optimism for the industry's prospects in the 1990s. Dr. Stanley Nealey examines this in his book, *Nuclear Power Development*, using public survey data and his own research on issues facing industry, regulatory agencies, utilities and the financial community. Nealey is an organisational psychologist at Battelle's Human Affairs Research Centers in Seattle, Washington, where he has done considerable research on mass media influences on public opinion.

Although the main reason for the nuclear industry's decline was the drop in demand, Nealey lists four others: a loss of confidence by the financial community in the abilities of management; over-regulation; escalating costs compared to coal; and, changing public attitudes about safety, waste disposal and conservation. These are the key issues, according to Nealey, that the industry must address.

Nealey explains these issues in a well organised manner, by discussing factors of importance to: (a) the financial, regulatory and political sectors; and, (b) the public. The latter is further divided into the "involved" public, who are knowledgeable and attentive to the issues, and the much larger "uninvolved" public, who are mainly concerned about plant safety, but who otherwise have no strong views. This structured format is effective because it separates those who make the decisions from those who influence the decision makers. For example, plant safety is very important to the public, but is not viewed as important by the financiers because they believe that the plants are safe enough. Better predictability of costs is essential to the lending institutions, who therefore favour design standardisation, shorter construction time, smaller plant size, and in particular a more stable regulatory environment.

On regulatory issues, Nealey cites a DOE study which urges "... a comprehensive and integrated campaign to eliminate unwarranted institutional (primarily regulatory) impediments to the future development of civilian nuclear power..." Even the NRC recognises problems of over-regulation; their 1981 survey of utilities indicated that the numerous "cut/weld/fix" requirements, imposed after TMI, hurt the industry and "may not have contributed to overall safety." According to Nealey, a "more tempered" regulatory climate is essential for the industry to prosper.

Because politicians effect legislation and thereby influence NRC regulations, political issues are analyzed. However, as Nealey concedes, such matters are difficult to assess because politicians "mirror the public attitudes." Nealey argues that most politicians are supporters of nuclear power (as evidenced by lobbies for NRC reform and reactor standardisation), but take a "public stance of scepticism and vigilance," because of public concern for safety. Public opinion polls are required reading by elected officials, and according to Nealey, public opinion is strongly coupled to mass media. Because the involved public tend to be very vocal and controversial, their activities are closely monitored by the media who provide the fan into which controversy hits. Nealey suggests that a rash of plant operating problems affecting capacity factor, or safety related incidents affecting public concerns, would mobilise the activists; they would use the media to coerce public opinion. Therefore, public acceptance is essential for future nuclear power development.

More than half of Nealey's discussion is on public attitudes. Several aspects of nuclear power, including regulations, safety, Chernobyl, the need for nuclear power and other energy technologies, are discussed effectively with ample use of public opinion survey data. He illustrates his point quite well, that, although public support has declined over the last decade, public acceptance has actually increased. Nealey bases this on careful analysis of how survey questions are phrased, which is often as important as the actual questions. When one survey asks "Do you favour development of more nuclear power?," there are more now who say "No" than there were ten years ago. However, when another survey with different phrasing of the question asks "Do you favour development of nuclear power to meet our future energy needs?," there are more now who say "Yes" than there were ten years ago. Also, when asked "do you favour shutting down the nuclear power plants," a clear majority say "No." Nealey argues that such attitudes imply not support, but "grudging acceptance." Even after the Chernobyl accident, a 2 to 1 majority opposed closing the plants while 78% opposed building new ones "at this time." The implication, concludes Nealey, is that most would be supportive given the right circumstances, i.e. to meet the nation's energy needs.

In his concluding chapter, all of the main points are conveniently summarised, guiding the reader to his conclusions. The prospects for nuclear power development, concludes Nealey, depend on five elements:

1. There must be a need for power that can not be met by conservation or alternate energy sources that are more popular with the public;

2. It must have a life-cycle cost that is cheaper than coal;
3. Financial institutions must be able to predict the costs more accurately, which implies shorter construction time, modular construction, smaller size to better match the growth curve (assurance of demand when built) and design standardisation for shorter and smoother regulatory approval;
4. The public must be convinced that they are safe, which may require demonstration of advanced reactors rather than modifications to existing designs; and
5. The currently operating stations must demonstrate a sustainable period of high reliability and efficiency (high capacity factor) with no safety related incidents.

Nealey's book is quick and easy to read (only 76 pages). His analysis is not extensive, but it is well focused on the key issues of media influence on public opinion and concerns of the financial institutions. Although based on U.S. data, the points of discussion are very relevant here in Canada.

Reports of Interest

Canada's Radiation Scandal?

A response by the Atomic Energy Control Board to a document issued last year by Greenpeace, which made a number of erroneous and exaggerated claims about the danger of radiation and Canadian standards.

This is an invaluable reference for anyone ever involved in discussions with the public.

- available from the Atomic Energy Control Board, P.O. Box 1046, Ottawa, Ontario, K1P 5S9, as report no. INFO-0362

Design of SES-10 Nuclear Reactor for District Heating

A general description of the SES-10 unpressurized, pool-type reactors designed by AECL Research to supply energy for hot water district heating systems.

Prepared for presentation to the International Conference on Conventional and Nuclear District Heating held in Lausanne, Switzerland, March 18-21, 1991.

- available from AECL Whiteshell Laboratories, Pinawa, Manitoba, R0E 1L0, as report no. AECL-10222.

Safety of Nuclear Installations – Future Direction

The proceedings of an international workshop sponsored by the International Atomic Energy Agency and Argonne National Laboratory, held in Chicago, August 1989.

- available from the IAEA, P.O. Box 100, Vienna, Austria, as report IAEA-TECDOC-550.

Correction

One of the books reviewed in the last issue had an error in the title. It should have read, "**Fission Product Transport Processes in Reactor Accidents.**"

The book was edited by J.T. Rogers of Carleton University and is published by Hemisphere Publishing Corporation.

Twelfth Annual CNS Conference

This year's joint CNA/CNS conference will be held June 9 to 12, 1991 in Saskatoon, Saskatchewan.
For the technical program 96 high quality papers have been accepted for presentation in a wide variety of nuclear related subjects. The preliminary program (below) gives a flavor for the range of subjects covered. In addition the CNA will be running parallel sessions on broad issue-based topics. This year's Conference Theme is "Nuclear Technology – Building Our Energy Future."

An interesting and educational non-technical program is planned as well. There will be three sponsored luncheons with speakers, a Western Barbeque/Rodeo on Tuesday evening, and a variety of tours including a flying trip to Key Lake. A spouses' program is being arranged.

Arrangements have been made with Air Canada to be the official "Sponsoring Airline." Discounts on air fares are available to those travelling to the conference.

Preliminary registration information will be sent out shortly. For further information, contact Al Wight at (416) 592-7285.

1991 CNA/CNS Conference – Saskatoon

PRELIMINARY CNS PROGRAM

Sessions:

Monday pm

1.1 Reactor Physics I
1.2 Thermal-Hydraulics
1.3 Industrial Irradiation
1.4 Computer Applications

Tuesday am

2.1 Fuel Channel Analysis
2.2 Reactor Physics II
2.3 Small Reactors
2.4 Severe Accidents

Tuesday pm

3.1 Fuel Behavior under Accident Conditions
3.2 Reactor Components
3.3 Safety Related Computer Software
3.4 Miscellaneous Topics/Medical Applications/Reactor Operations/Environmental Protection

Wednesday pm

4.1 Nuclear Fuel Management
4.2 Fuel Behavior and Performance
4.3 Reactor Safety
4.4 Reactor Engineering
4.5 Nuclear Waste Management and Uranium Mining and Processing

New CNS Award

Following a suggestion by Joe Howieson (Sr), a former president, the CNS Council had decided to sponsor an award for Innovative Achievement. This is the first award established by the Society.

It is hoped that the first presentation can be made this year at the Annual Conference in Saskatoon in June, if suitable candidates are nominated.

Brochures announcing the new award and inviting nominations have been mailed to all members. Nominations can be sent to the CNS office and should be received by April 30.

CNS Innovative Achievement Award

The inscription reads, "Honours the dedicated men and women who bring the benefits of nuclear technology to Canada and the world."

Ontario Premier Replies

Last November the CNS Council decided to write to the newly-elected Premier of Ontario, Robert Rae, before his government presented its program in the Speech from the Throne. That letter, and excerpts from the Throne Speech were published in the last issue of the Bulletin, *Vol. 11, No. 3.*

Following is the letter Premier Rae sent to CNS President Hugues Bonin in late December.

Dear Mr. Bonin:

Thank you for your letter of November 15, 1990, expressing your organization's concerns about the future of nuclear energy in Ontario.

As the Brundtland Commission has said, "Choosing an energy strategy inevitably means choosing an environmental strategy." The New Energy Directions, announced by the Government in the recent Throne Speech, were developed with this key concept in mind.

The New Energy Directions will both reduce the effects of energy use on the environment and strengthen our economy. Our priorities are to improve the efficiency of energy and electricity use, develop renewable and small scale sources of energy and to secure greater involvement of northern and native people from Hydro's ongoing and proposed northern projects and activities.

Ontario Hydro will have a crucial role in ensuring the success of these policy priorities. The Government is providing policy direction to Ontario Hydro so that they accelerate targets and efforts on demand management, energy conservation and parallel power generation, cancel plans to spend $240 million on developing new nuclear stations, and redirect that money to conservation programs. As well, we have directed Hydro to ensure the safe and reliable operation of existing nuclear generating stations, including all four units of the Darlington station.

The Government has authorized Ontario Hydro to enter into a long term agreement with AECL to improve the operating performance of its existing nuclear stations. Ontario Hydro has been asked to give priority to the early environmental assessment of hydro-electric projects at new and existing sites and transmission facilities to bring electricity from Manitoba and to work to ensure that northern and native communities benefit from Hydro's proposed and ongoing activities.

Furthermore, the Government has decided that the Environmental Assessment Board review of Ontario Hydro's plans will continue.

Our New Energy Directions put conservation, renewable energy and small power generation ahead of the nuclear option. At the same time, we recognize the important role nuclear power plays in meeting the Province's needs for electricity services. I agree that the Environmental Assessment Board hearings are an appropriate forum to consider the energy options available for meeting future demands for electricity services, including nuclear power.

I appreciate you sharing your organization's concerns with me and your kind congratulatory words.

Yours sincerely,
Bob Rae

Romanian Society Formed

Thirty years to the day after the formation of the CNS, its Romanian sister society, the Associata Romana Energia Nucleara ("AREN"), came into being in Bucharest on 1990 August

30. Its charter was subsequently ratified by the Bucharest municipal court on October 30. Keith Bradley, CNS Treasurer, recently met in Bucharest with the President, Mr. Horia Mocanu and its Vice-President, Mr. Teodor Ionescu to follow up CNS's invitation, transmitted by past President Ken Talbot, to enter into an agreement of cooperation between CNS and AREN.

The Association now has 65 members from seven organizations, many of which are familiar to Canadians who have been involved in the Romanian nuclear program. They include ISPE ON, ICN Pitesi, IFA Margurele, CNCAN, INC, Nuclear Montaj and AECL CANDU (one member!). AREN is discussing association with the European Nuclear Society and is very keen to increase its international links. Its executive were therefore very pleased to receive CNS' proposal, which provides for promotion of information exchanges and exchange visits, exchange of publications and complimentary conference registration for official attendees. CNS' Phil Stubley, located at the five unit Cernavoda CANDU 600 station now under construction, has given considerable encouragement and assistance to AREN in getting established.

The Association is planning shortly to publish its magazine "Revista Energia Nucleara." Its prime focus at first will be to a general audience to address issues of public perception. While the ultimate objective is to adopt a more technical orientation, the Association expects that public acceptance will become a critical aspect of nuclear power development in Romania over the next few years. Romania is undergoing a profound transition from a closed and controlled society to one in which many viewpoints are finding expression, including an incipient anti-nuclear movement, which would equate Cernavoda to Chernobyl. The general public is not as critical as that in comparable Western countries, so that the Association can play an important role as a non-institutional advocate of nuclear energy. Amongst the features planned is regular translation of items from "CANDU Update," the AECL CANDU in-house information sheet. Of especial interest are articles which address common concerns about nuclear energy.

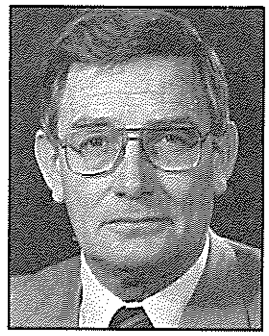
A key challenge of the Association is finding the resources to publish the review. The paper required for a single printing is extremely difficult to find and costs the equivalent of two months' of an engineer's salary. It is common practice in offices to use newsprint in photocopiers – and to use both sides of it. Another problem is the unavailability of personal computers to prepare the text for the publication. To reduce printing costs, it is necessary to generate text files which can be used directly by the printer. In general, the lack of availability of Western publications is a key handicap for Romanian engineers. The critical state of Romania's economy has prevented more than a tiny number of periodicals such as *Nuclear Engineering International, Nucleonics Week* or *Nuclear News* from being available. Suggestions would be welcome on how copies of these publications, even if they are up to ten years old, could be made available to AREN and its members.

News of Members

John Graham, until recently Director of Licensing at AECL Research, has joined BNFL Inc., a new subsidiary in the USA of British Nuclear Fuels Limited, as Manager of Environmental Health and Safety and of Quality Assurance. He will be located initially in Denver, Colorado.

As noted in the last issue of the *Bulletin*, John is a candidate for Vice-President (President-elect) of the American Nuclear Society.

Keith Nuttall has been appointed as Chairman of the Waste Management and Environmental Affairs Division of the CNS. He is currently at AECL's Whiteshell Laboratories.



Bill Morison

Bill Morison has retired after 41 years service with Ontario Hydro where he was Vice-President, Design and Construction. Bill has been a key member of the Canadian nuclear program since the 1950's when he conducted most of the safety studies for the Douglas Point NPP. He went on to oversee the engineering of the original Pickering station (now called Pickering A) and subsequently of all of Ontario Hydro's engineering.

His successor as V.P. Design and Construction is **Don Anderson**, formerly Director, New Business Ventures.

Branch News

Central Lake Ontario

On December 19, 1990 about 100 people attended a luncheon presentation at Darlington NGS on **Japan's Advanced Thermal Reactor** (ATR) program by Phil Connor of Ontario Hydro's New Business Ventures. Ontario Hydro is a supplier of heavy water to Japan for use in the ATR program.

The Advanced Thermal Reactor is a heavy-water moderated boiling light water cooled reactor developed in Japan with outstanding flexibility regarding nuclear fuel utilization of plutonium, recovered uranium and depleted uranium. ATR has been developed as a national project in Japan since 1967.

Its prototype reactor "Fugen" (165 MWe) has been in commercial operation since 1979 with a load factor of approximately 62% and total electrical output of 8.05 billion KWH, achieving approximately 50,500 operating hours by the end of March 1988. A total of 385 MO*x* and 362 UO_2 fuel assemblies were loaded into the core and 247 MO*x* and 276 UO_2 were discharged with no fuel failure up to the present. The current core consists of 138 MO_9 and 86 UO_2 assemblies. Fugen has been developed and operated by the Power Reactor and Nuclear Fuel Development Corporation (PNC).

The Japan Atomic Energy Commission (JAEC) decided to develop a 600 MWe class demonstration plant in 1981, and nominated the Electric Power Development Company (EPDC) to undertake the construction and operation of the plant in close cooperation with electric utilities and PNC in 1982. At present, a 606 MWe demonstration plant program is proceeding with the target of commercial operation in 1998.

The construction of subsequent plants will be dealt with by taking into consideration such factors as the state of construction of the demonstration plant, the economy of ATR and plutonium balance in Japan.

Ottawa

The Ottawa branch has enjoyed several interesting talks over the past few months.

Back before Christmas (but too late for the last issue of the *Bulletin*) the Branch was treated to an erudite review of accidents and a discourse on safety management by David Mosey (former editor of the *Bulletin*). Much of the material Mosey presented was drawn from his recent book "Reactor Accidents" which was reviewed in the Fall 1990 issue of the *Bulletin*.

In January John Lipsett from AECL-CRL, stepped in on short notice to present some intriguing views under the title of "Thinking About CANDU's Future." His talk evoked a lively discussion.

Studies on the transmutation of nuclear wastes being conducted by Japan and the USA were the subject of John McKeown's talk in February. The concept is to irradiate the waste using a high-power accelerator. AECL Accelerators is participating in this work through a contract with the Power Reactor and Nuclear Fuel Development Corporation of Japan.

To Branch Executives

Let the rest of the CNS know about your activities.
Mail or Fax your news directly to the editor at:
9 Sandwell Crescent, Kanata, Ontario K2K 1V2;
Fax (613) 820-3593; or, if it is more convenient,
to the CNS office.
Deadline for the next issue will be mid-June.

Membership

Over 100 new members! That is the report from Jerry Cuttler, CNS Membership Chairman.

We at the *Bulletin* send greetings to all these new readers. As a gesture of welcome the names of all new members as of the end of March are published below.

This year a CNS coffee mug is being sent to all paid-up members as a special bonus. In addition, sponsors of new members will receive either a CNS tie or scarf (their choice). A membership form is included in this issue so that you can give it to any prospective member you know. If every current member signed up a new member the organization would quickly double which would give the Society more influence and enable it to offer more services.

Finally, Jerry informs us that there are still a number of CNS pins available. If you want one, contact the CNS office.

CNS New Members

Raja Abdallah
John A. Aikin
Joel Almon
David John Andrews
Vern Austman
C. Colin Barfoot
Charles F. Bedford
Leslie Diane Bell
Ben A. Bjorkenstam
Ian Braff
John R. Britt
Gilles Brouillette
Jacqueline Busca
J. Vincent Chung
David Marvin Cole
K.A. Cornell
Ian Dean Cruchley
Roderic D. Delaney
Donald F. Dixon
Robert S. Dixon
Nicholas N. Ediger
Mike Elia
Chris D. Francis
Peter J. Fundarek
Andres V. Galia
Diane Gallant
William H. Gardiner
Normand Gilbert
Andrew S.R. Godo
Claude Grandmaison
Don Gratton
Chantal Guertin
Jim Hammond
John R. Harries
Michael Hart
S. Ahmed Hasnain
Dr. Peter F. Hinrichsen
Dr. Alain Noudayer
Stephanie J. Hunn
David A. Jenkins
Dr. Robert E. Jervis
David R. Jones
Margarete Kalin
James A. Kennedy
Dr. Jean-Pierre Labrie
Bob Lacoursiere
Jeff Lafortune
Martin Leek
Ron Lewis
John C. Luxat
Dr. Gerard Lynch
Gordon Mallory
Corneliŭ Manu
Dr. Augustine C. Mao
Allan McConnell
Gary R. McCormack
Gerald P. McPhee
Mme Meziere
Piers R. Mitchell
Dr. R. Moridi
David Taro Morikawa
Katherine Moshonas
Victor Murphy
Norman J. Naylor
Ian E. Oldaker
Dr. Emilio Panarella
Dr. Duane R. Pendergast
Christian Pepin
Raymond C. Quan
Charles Quon
Silvano Ravera
John K. Riley
John Robinson
Joachim Rosen
Dr. Rene Roy
Robert P. Rulko
Gilles Sabourin
Keith John Sadler
Dr. Norman H. Sagert
Paul D. Schofield
Ephraim Schwartz
Grant Sheng
David Shier
Steven Craig Sholly
Vaclan Rudy Sligl
Ron Stark
Philip H. Stubley
Vincenzo Tassone
J.G.V. Taylor
Ian Thomson
W.E. Tilbe
David Tregunno
Jeffrey D. Van Eenoo
Gordon P. Verdin
Richard Vyrostko
Leslie Wardrop
Martyn R. Wash
John Webb
Chris Westbye
Paul P.H. Wilson
Michael G. Wright
Ali A. Zaidi
Syed Zaidi
Roy Zanatta

Keeping Your Fuel Cool

A Layman's Guide to Avoiding Meltdown

Roger Steed

Ed. Note: *One of the pressing, on-going questions facing the nuclear industry and CNS members, as the professionals of that industry, is how to convey some basic concepts about safety to the interested public. Following is an attempt by Roger Steed, chairman of the New Brunswick Branch, to explain that potentially frightening event, a "melt-down," which is still remembered by some as the "China syndrome."*

Roger, and we, would be interested in your reactions and comments.

Please note that most of the illustrations used by Roger have been omitted as being unnecessary for a CNS audience.

Perhaps the concern that should be uppermost in the mind of anyone operating a nuclear power station is how to ensure that the heat generated in the uranium dioxide fuel pellets in the reactor by either nuclear fission of the uranium and plutonium atoms or decay of their fission products can be adequately taken away to a "heat sink" at all times, so that the fuel pellets, and ultimately the reactor as a whole, will not "melt down."

To start right at the very beginning, why is it necessary to cool the fuel of a reactor? After all, the hotter it is, the more heat we can use to generate steam to drive the turbine to spin the generator to make more electricity. Not quite! Let's look at where the heat comes from, to see why keeping the fuel "cool" is important.

Where the heat comes from

Nuclear fuel for many of the world's reactors, ours included, is made from uranium dioxide powder, compressed into round cylindrical pellets, which are baked in a furnace to sinter the powder into a solid ceramic (Fig. 1, Item 5). A stack of 31 of these pellets is inserted into a tube (Item 2) of an alloy of zirconium, and the ends of the tube sealed with end caps (Item 3) which are welded in place. For our reactor, 37 of these tubes containing uranium dioxide pellets are held together in a bundle between two end plates (Item 4), making one so-called fuel bundle, 19½ inches long and about 4 inches in diameter, weighing about 52 lbs. Our reactor has twelve of these fuel bundles in each of its 380 fuel channels, for a total of 4560 bundles (Fig. 2, Item 8, and Fig. 3, Item 3). But we still haven't said where the heat comes from!

Uranium is mainly composed of two kinds, or isotopes, uranium of atomic weight U-235, and U-238. Only the U-235, which comprises only 0.7% of the total in naturally occurring uranium, is able to fission, or split into two. As a U-235 atom fissions, it usually splits into two unequal, highly radioactive fragments, at the same time giving off between two and five subatomic particles from the atomic nucleus called neutrons, some highly energetic gamma rays, and some heat (Fig. 4). Some of the neutrons released are captured in the U-238, ultimately producing plutonium, which also fissions, while other neutrons are slowed down, or moderated, as we say, by the heavy water between the fuel channels, and as long as just one of these neutrons from the original fissioning uranium atom collides with another uranium atom to cause it to fission, our self-sustaining chain reaction will keep going (Fig. 5).

To control this rather interesting business, we are able to insert neutron absorbing material into the reactor (ordinary or "light" water curiously enough) or remove it. If we add light water to the special control compartments in the reactor (Fig. 3, Item 27), more neutrons will be absorbed and therefore be unavailable to cause further fissions, the rate of uranium atoms fissioning will slow down, and the amount of heat or power produced will decrease. Conversely, removing some of the light water in the compartments will cause power to increase.

The heat from those fissioning uranium or plutonium atoms must be conducted away, in our reactor by the heavy water coolant which circulates past the 37 individual elements of each and every fuel bundle. The heat, obviously, is used to generate steam, and ultimately, electricity. However, if for any reason the heat is not removed at the same rate at which it is being produced, the fuel temperature will increase, and the fuel pellets and the tubes containing them may melt, thereby releasing much of the highly radioactive fission fragments into the heavy water coolant, and possibly damaging the reactor structure itself. This is what happened at Three Mile Island.

In addition, the fission fragments themselves release heat as they "decay" to more stable atoms. Initially as much as 7% of the heat produced at full power is still being produced by the decay of these fission products when the fission process is stopped to shut down the reactor. Thus, even though the reactor may be shut down, we still must be able to remove heat from the fuel.

So now you know where the heat comes from!

This heat, incidentally, can be pretty considerable. The temperature at the centre of the fuel pellet can be as much as 1827 degrees Celsius as the fuel bundle containing it produces its nominal design power. All 4560 fuel bundles in the reactor together produce about 2061 Megawatts of heat to generate the steam to drive the turbine to drive the generator to produce 680 Megawatts of electricity (Fig. 6). 1000 kilowatts = 1 Megawatt, by the way.

Where the heat goes

Clearly, all this heat must be taken away very efficiently from the fuel and indeed the reactor, or the fuel pellets, their zircalloy sheathing, and the pressure tubes containing the fuel bundles, will melt, wrecking the reactor, thereby releasing a great deal of radioactive fission products to the inside of the reactor building. Not good! As heat will only flow by itself from a hot body to a cooler body, downhill, as it were, we talk about a "heat sink" as the place where the heat is going to end up. With all this heat to dispose of, it's vitally important to have a heat sink at all times, so much so that it is a condition of our operating license that we must also at all times have an alternate heat sink to fall back on should the primary heat sink become unavailable.

The reason for this heavy emphasis on being able to get rid of the heat, by having an assured heat sink, is that, quite unlike a coal, oil, or gas fired boiler which stops producing heat when the fuel supply is shut off, even though one stops the fission process in a nuclear reactor, heat is still being released as the highly radioactive fission products in the fuel "decay" to more stable atoms. While the amount of decay heat reduces with time, initially, immediately after a reactor is shut down from full power, the decay heat is roughly 7% of that produced at full power. So being able to cool the fuel is pretty important, and while the title of this article may seem a little facetious in the light of the rather high fuel temperature I mentioned earlier, the fuel can get a lot hotter if we don't cool it.

So let's trace the flow of fuel to see where it ends up. You may find it helpful to refer to the diagram, Figure 7.

I show the fuel, the source of the heat, at the left hand side of the diagram, and the flow of heat or energy is generally towards the right of the diagram where I show the various heat sinks. Let's consider what goes on as the station operates normally at full power. The heat flow is shown with a double heavy line.

Heat from the fuel is picked up by the circulating heavy water coolant flowing over the fuel (Fig. 8), and is carried to the steam generators, or boilers (Fig. 9, Item 8, and Fig. 10, Item 18), where the hot coolant flows through the 3,500 or so tubes in each of the four boilers to give up its heat to ordinary, or "light" water on the outside of the tubes. This light water, which we also call boiler feedwater, is at a lower pressure than the heavy water, and so is able to boil, and turn into steam. The steam is conducted away from the boilers to the turbine where its thermal energy is converted into electrical energy. Industrial and domestic consumers of this electricity consitute the "load" on the generator, and thus a sizeable part of the heat sink. The laws of thermodynamics don't permit a turbine to completely convert all the energy of the incoming steam into mechanical energy. Unfortunately, almost two thirds of the heat energy in the steam is still present in the seawater passing through the thousands of tubes in the condensers below the turbine, where the exhaust steam from the turbine is condensed into water, eventually to be pumped back into the boilers as feedwater all over again (Fig. 6). So, for Point Lepreau, the Bay of Fundy is the other major heat sink even when we are operating at full power.

What I have just described is the main flow of heat from the fuel. There are several other smaller heat flows which occur quite normally while the station is at full power. These are shown with a single solid line on the heat flow diagram (Fig. 7). The heat from slowing down, or moderating, the fast neutrons which are emitted from the fissioning uranium and plutonium nucleii must be removed from the heavy water moderator which surrounds the fuel channels. Accordingly, the heavy water moderator is pumped through the tubes of the two moderator heat exchangers (Fig. 8, and Fig. 10, Item 4), where its heat is given up to ordinary, or "light," recirculating cooling water, flowing on the outside of those heat exchanger tubes. The recirculating cooling water in turn is pumped through other heat exchangers where its heat is given up to sea water pumped out of, and back again into, the Bay of Fundy. Other station auxiliaries too numerous to go into here also reject heat to the recirculating cooling water.

So much for normal full power operation. Occasionally situations may arise in which the normal flow of electricity from the generator is interrupted, or for some reason the turbine becomes unable to accept steam, and yet it is still desirable to keep the reactor at power. Lightning may strike our transmission lines, causing very large circuit breakers to open to protect the generator, and other vital electrical equipment. When this happens, very large valves open immediately to allow the steam to bypass the turbine and go directly to the condenser, and reactor power is "set back" at one per cent per second to 60% full power. Thus all the heat energy of the steam from the boilers is given up directly to the Bay of Fundy. Once the situation returns to normal the circuit breakers are closed, and the steam bypass valves slowly close to redirect the steam back to the turbine, and the electrical "load" on the generator becomes the main heat sink again as the reactor is returned to full power.

Another perfectly normal situation occurs once each year when the station is shut down for its annual maintenance "outage" when we perform maintenance which cannot be done "on-line." At this time we may dismantle parts of the turbine and generator, or perhaps repair a boiler tube leak, or change the seals of one or more of the four very large reactor coolant circulating pumps (Fig. 11). As I've described earlier, it is still necessary to remove the "decay" heat from the fuel, so a special "shutdown cooling" circuit of pumps and heat exchangers is brought into play, allowing the heat from the fuel to bypass the boilers, turbine, and generator altogether, and instead sending it via the recirculating cooling water straight to the Bay of Fundy.

Perhaps you may be becoming a little concerned about all this heat going to the Bay of Fundy! Our cooling water is taken from the Bay through an eighteen foot diameter tunnel under the sea floor almost half a mile long, with its entrance west of the tip of the point, and is returned to the sea about twenty-three degrees celsius warmer through another tunnel with its exit east of the point. Although sensitive instruments can detect a "thermal plume" from the tunnel exit, the latter is specially designed to mix the warm water sufficiently with the surrounding seawater to avoid damaging marine life. This discharge of heat to the Bay is not something peculiar to a nuclear power station. Oil or coal fired "thermal" plants must do the same. Fortunately the Bay of Fundy is pretty cold, and we are in no danger of warming it up excessively. Those of you who have tried to swim in it will appreciate our efforts!

So far we have been discussing perfectly normal operation. It is time to turn our attention to abnormal, or emergency, situations, through all of which it is still imperative to "keep the fuel cool."

Coping with the abnormal

Though we go to considerable lengths to avoid it, we may be unlucky enough to suffer a pipe break in the reactor coolant circuit, or LOCA, or loss of coolant accident. Should this happen, several things will happen automatically to mitigate the consequences of this serious accident: the reactor's two shutdown systems will immediately "fire" to terminate the fission process (Fig. 3, Items 24 and 29), thereby immediately reducing the heat being produced in the fuel to about 7% full power, the water held up in the "dousing tank" in the dome of the reactor building (Fig. 10, Item 1) will be released as a very heavy "rain" to condense the escaping steam, the main steam safety valves will be opened to discharge all the steam from the boilers to atmosphere to "crash cool" the boilers, and hence the reactor, and very shortly the emergency core cooling system, or ECC, will begin to inject stored water at high pressure into the circulating heavy water coolant circuit to replace water that is flowing out through the break. The hot water collecting on the floor of the reactor building is then pumped through the ECC heat exchanger to cool it by rejecting its heat to recirculating cooling water before re-injecting it back into the reactor. A glance at the diagram will show all the heat flows in this nasty scenario. The station might continue in this manner for several days or weeks until plans and preparations were completed to repair the break.

Another hopefully unlikely event that the station is designed to cope with is an earthquake. While the reactor and its associated piping is designed to withstand one, the greater part of the rest of the station is not. Accordingly, we have a "seismically qualified" Emergency Water Supply, or EWS, as we call it, which is able to pump water from our on-site reservoir either to the boilers to act as feedwater to be turned into steam which we would release to atmosphere, or to our ECC heat exchanger and back again into the reservoir. It is designed to withstand the most severe earthquake we're likely to suffer, and would replace our turbine-generator and recirculating cooling water system as heat sinks, which would likely be destroyed in a severe earthquake. Once again we have been able to preserve a heatsink in order to guarantee that the heat from the fuel can be safely removed.

The worst, and fortunately for us, the least likely accident we should encounter, is a loss of coolant accident coupled with a completely unavailable emergency core cooling system. This is not good! Our fuel would be slowly heating up, the heavy water coolant having run out of the pipe break onto the floor without any emergency core cooling water to replace it. Fortunately, the fuel channels which contain the fuel are surrounded by the heavy water of the moderator. So, while the fuel channels' pressure tubes (Fig. 2, Item 9) would likely be damaged beyond repair as they slumped down onto the calandria tubes which surround them (Fig. 2, Item 10 and Fig. 3, Item 3), due to the heat being released from the fuel, at least we still have a heat sink. The heat imparted to the moderator would be taken away by the moderator heat exchangers in exactly the same manner as we discussed several paragraphs ago. Very expensive, true, but through all of this, neither the fuel nor the reactor have suffered "meltdown."

Something we haven't talked about so far is where the electric power is going to come from to drive all the pumps to circulate all the water we've been relying on to carry away all the heat. It's a vital part of the story, so we'd better go into it.

Sources of electricity

In a Canadian nuclear power station, power supplies for all the electrically driven auxiliaries are divided into classes, depen-

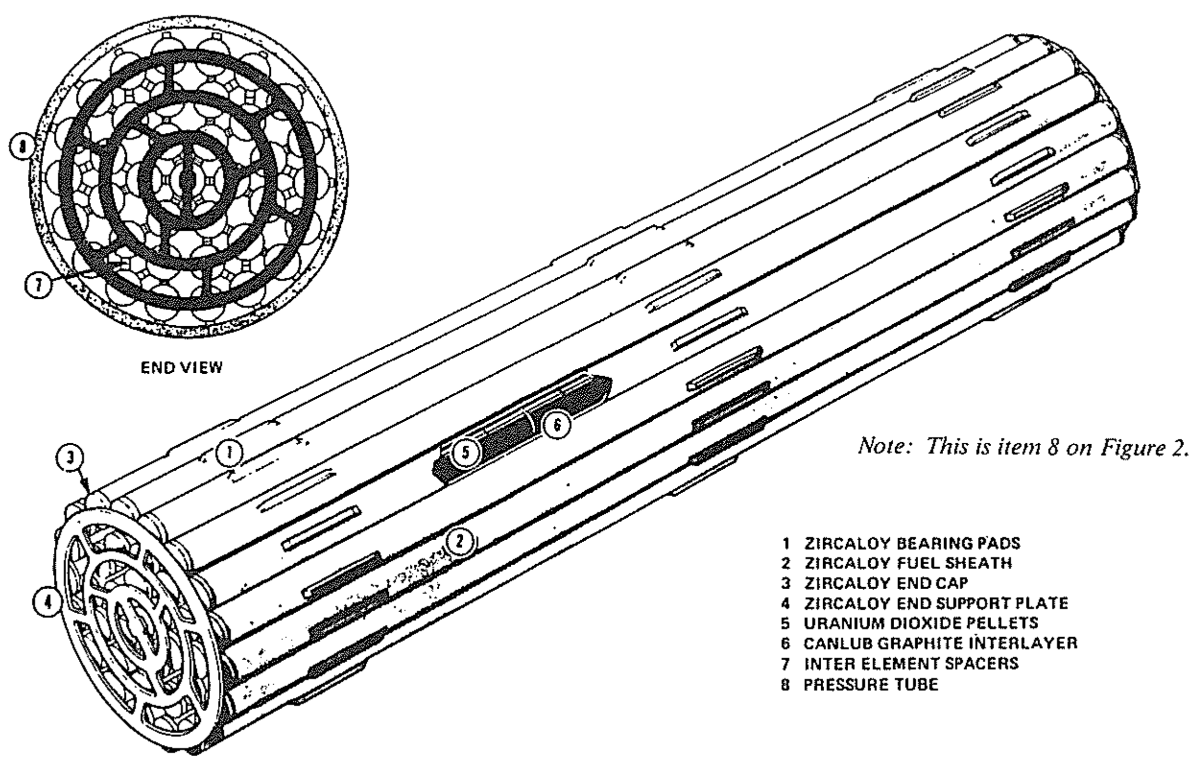


Figure 1. 37-element fuel bundle

ding upon how reliable they are, and just as you might expect, the motor of a pump, for example, is supplied with the class of power appropriate for the job, this depending upon the consequences of not being able to operate the pump in question.

Class IV power, the least reliable of all, comes either from the generator itself, or from "the grid," which is really all the other power stations around, half from each, to be precise. All our large pumps which must operate whenever we are running at anything greater than about 2% full power are supplied from Class IV. However, we may become separated from the grid, and we may not be capable of running the generator at that time, so we have Class III power, normally supplied from Class IV, but provided by two standby diesel generators when Class IV is not available, to run the smaller pumps which must run when the station is operating at low power. These diesels, incidentally, are poised to come to life immediately upon the loss of Class IV power, and are each run every two weeks for at least four hours to be sure that they will be available whenever required. We have occasionally performed a "Loss of Class IV" test to prove that the station will respond correctly to this upset. Classes II and I are even more reliable, Class I being supplied from very large batteries which are constantly kept fully charged. However, all this may tumble down in an earthquake, so, we have a seismically qualified Emergency Power Supply, or EPS, consisting of two more diesel generators, to power the EWS pumps as well as the ECC pumps. To highlight the classes of power for all the pumps upon which we depend to maintain a heat sink, I have shown the pumps on the heat sink diagram (Fig. 7). Table 1 gives the number, capacity, and power supply class of these pumps.

If there is no electricity

It is worth noting at this point that, should all sources of electric power fail, we still have a couple of aces up our sleeve! We have found that the gravity-driven process we call "thermosyphoning," namely hot heavy water coolant flowing out of the fuel channels and up into the boilers, and cooler coolant flowing back down into the fuel channels, is quite adequate to carry away the heat from the fuel when the reactor is operating at low power. That's one of them! The other is our small steam turbine-driven boiler feed pump, which at anything less than 5% full power will provide adequate feedwater for the boilers to turn into steam, running on steam generated in the boilers in the first place. The latter is just one of many improvements conceived by the station staff, designed, installed, and commissioned after the station first started up.

This has been a rather long and tedious tale, but if you are still with me, you will have seen that very little has been left to chance to "keep the fuel cool." The chances of my neighbour being able to say almost indefinitely "another day without meltdown" are indeed pretty good!

Table 1. Pumps Required to Maintain a Heat Sink

Key # on Fig. 7	Name	Number	Capacity	Power Supply Class
P1	Main heat transport	4	All req'd at high power	IV
P2	Shutdown cooling	2	100%	III
P3	Emergency core cooling	2	100%	III and EPS
P4	Moderator	2	100%	III
P5	Condenser cooling water	2	100%	IV
P6	Recirculating cooling water	3	50%	III
P7	Raw service water	4	33%	III
P8	Condensate extraction - main	2	100%	IV
	- aux	1	5%	III
P9	Boiler Feed - main	3	50%	IV
	- elect. aux	1	5%	III
	- turb. aux	1	5%	steam
P10	Emergency Water Supply	2	100%	EPS

Note: Capacity in this context means the fraction of the total, full power, or normal, flow that the pump can carry. Thus it is only necessary to run one shutdown cooling pump, two recirculating example. The 5% pumps are auxiliaries run when the total flow requirement is less than 5%. All four of the main heat transport pumps must run whenever the reactor is at high power, although the station was designed to operate at up to 60% full power with only two of these running.

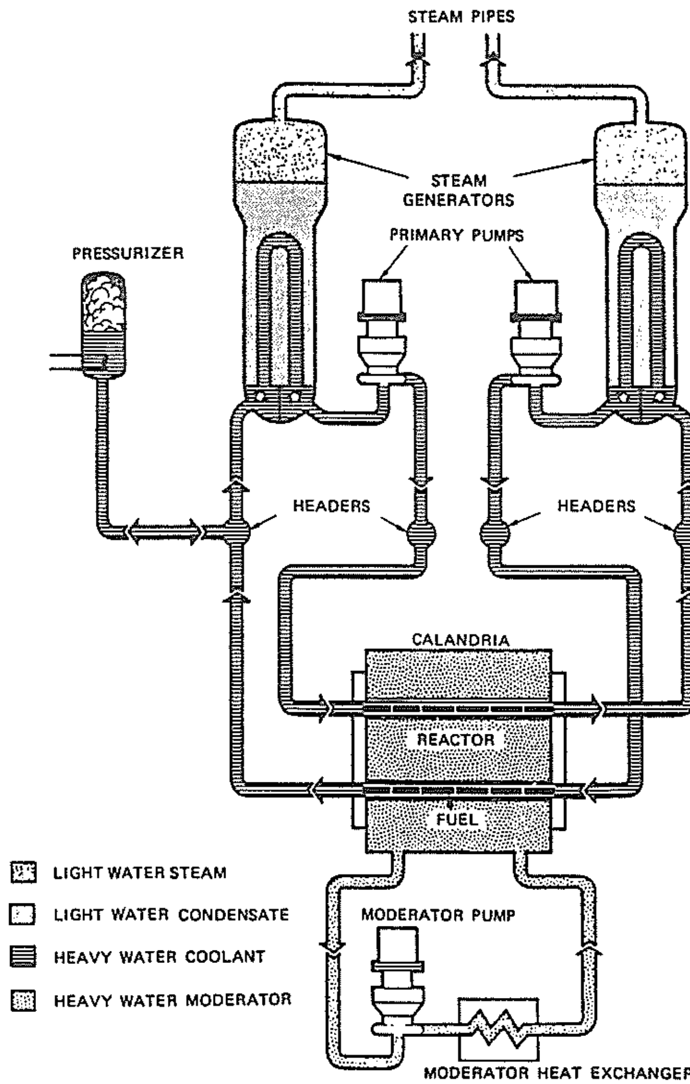


Figure 8. CANDU reactor simplified flow diagram