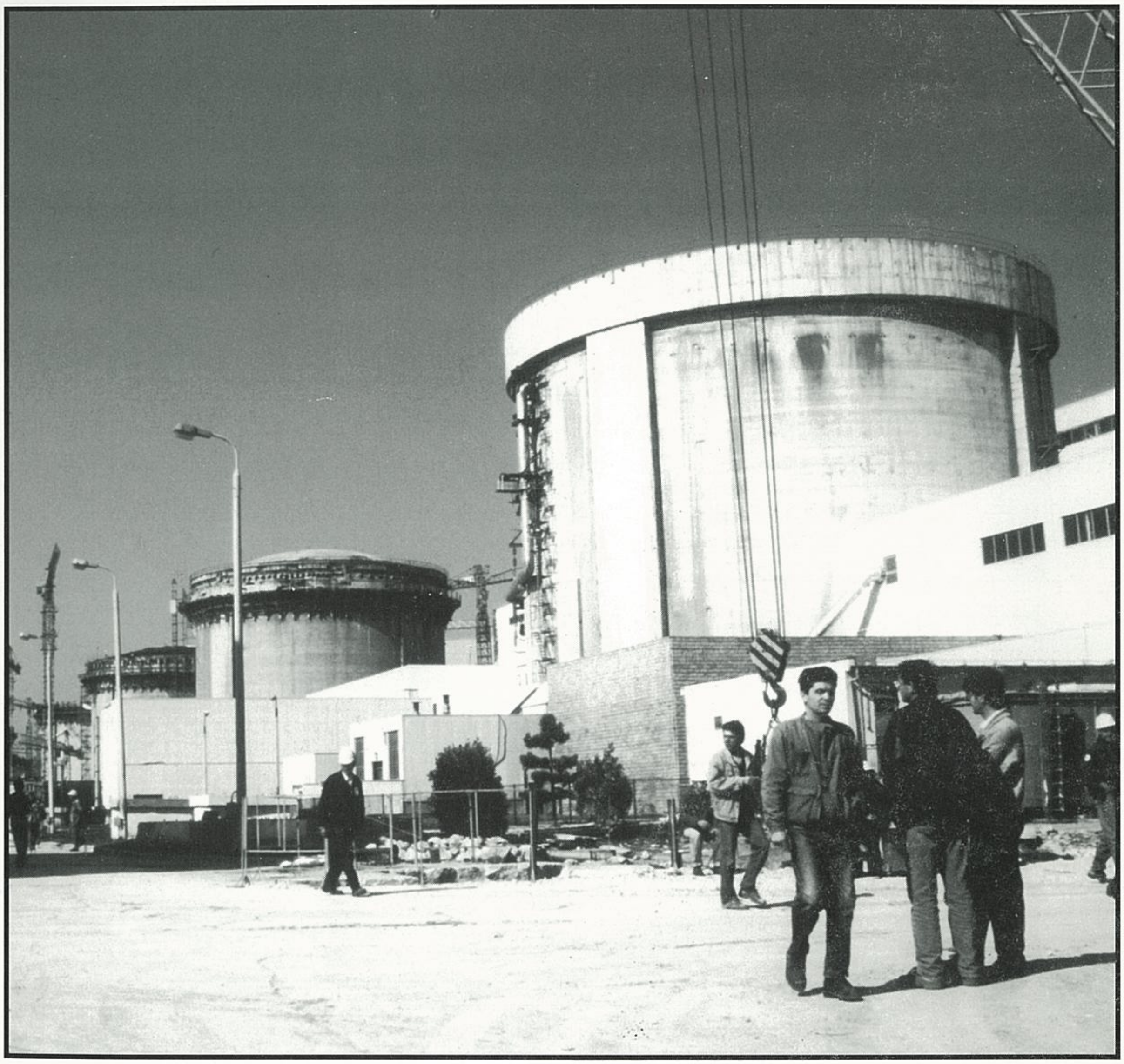
CANADIAN NUCLEAR SOCIETY
bulletin
DE LA SOCIÉTÉ NUCLÉAIRE CANADIENNE

Spring / Le printemps 1996 Vol. 17, No. 2



- Student Conference
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Cover Illustration

The photograph on the cover shows part of the Cernavoda project in Romania. Unit 1 in the foreground, which achieved criticality on April 16, 1996, is the first CANDU in Europe.

(Photo courtesy of Sandra Vaughan, Atomic Energy of Canada Limited)

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ISSN 0714-7074

The *Bulletin of the Canadian Nuclear Society* is published four times a year by:
The Canadian Nuclear Society
144 Front Street West, Suite 725,
Toronto, Ontario, Canada, M5J 2L7.
Telephone (416) 977-7620
Fax (416) 979-8356

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 $60.00 annually, $35.00 to retirees, $20.00 to students.

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Printed by The Vincent Press Ltd., Peterborough, ON

EDITORIAL

THE GOOD, THE BAD, THE QUESTIONABLE

Over the past couple of months there have been events which could we would categorize as "good", "bad", and "questionable".

As "good", we would note the start-up of the first unit at the Cernavoda plant in Romania. Seventeen years after the project began Unit 1 was brought to criticality on April 16.

The first decade of the Cernavoda project was mired in politics, poor management, questionable manufacturing and inadequate financing. After ten years there was not much more than five partially completed containment buildings and about 40 % of the equipment for unit 1 more or less installed. That the Canadian led team which took over the project in 1990, after the downfall of the former communist government, has managed to resurrect the project and bring Unit 1 to start-up is remarkable.

In the "bad" category there was the shutdown of all eight Pickering units because of one faulty valve. It is incredible that the high pressure emergency coolant injection system (which was a later addition to the plant) would have been designed such that the entire station was vulnerable to a single failure.

Back when the vacuum containment system was first proposed the designers were warned (and were aware) that any failure which rendered it not fully functional would require the shutdown of all units connected to it. At that time there were just four. When Pickering "B" was added the designers made a calculated gamble and added four more units to the same system. The high cost of the vacuum containment system may have justified that gamble but it is difficult to see the same argument for the ECI system. Whatever (minor) savings were achieved by having only one ECI system for all eight units and for designing it with little redundancy have been swamped by the tens of millions of dollars the recent shutdown has cost. Through bad design and inadequate maintenance Ontario Hydro Nuclear has suffered a significant loss, not only in monetary terms, but, also in credibility.

On the "questionable" side there is the on-going circus of the hearings into the concept for deep geological disposal of nuclear fuel wastes. It is questionable what the extended debate is accomplishing other than to keep the spectre of deadly radioactive waste before the public and providing a theatre for the histrionics of those opposed to anything "nuclear".

The fact that the hearings are dealing with a "concept" and not a real project adds to the ambiguity of the "debate". Even the Panel appears to be subject to this uncertainty by avoiding a central charge in its mandate - to determine the "acceptability" of the concept. the Panel has not even suggested how it will judge "acceptability". Those opposed to things "nuclear" will never agree that disposable is "acceptable in principle" since that could allow the continuation of nuclear programs.

Phase 1 of the hearings did little towards resolving the dilemma. The next round, which will examine technical aspects of the proposal, may clarify some aspects and identify detailed deficiencies but is unlikely to do much towards achieving a consensus on acceptability of the concept.

IN THIS ISSUE

One of the important events of the past three months was the **CNA/CNS Students Conference.** To reflect the significance of that gathering and to acknowledge the high quality of the presentations, we are including, as a Special Supplement, the three winning papers. Read them, You will be impressed (and informed).

In the regular Bulletin we have four **"Letters to the Editor"** (which is a record). Three deal with that increasingly controversial topic – the linear, no-threshold, dose - effect hypothesis for the biological effect of ionizing radiation.

There are three articles related to the **Hearings** on the **Nuclear Fuel Waste Disposal Concept** which are underway. One is a **review** of Phase 1 of the hearings, another is a summary of the **CNS Submission**, and the third is a **Commentary**.

In the technical area there is a description of the **Pickering Dry Storage** system from the recent CANDU Fuel Handling Conference, and a comprehensive overview of **Generic Code Validation** which will be presented at the CNS Annual Conference.

Two short notes deal with the root cause of the **Chernobyl Accident** of a decade ago and the start-up of **Cernavoda Unit 1.**

There is, of course, news of the Canadian Nuclear Society, especially of the activities in the Branches, and some other miscellaneous items.

Finally we have the ever intriguing "Darker Side" on the back page.

Our thanks goes again to all contributors, to associate editor Ric Fluke and, at this time when he is stepping down from his arduous year as CNS President, to Jerry Cuttler, for his constant support, occasional cajoling and frequent contributions.

Your comments are always welcomed.

DEADLINE

The deadline for the next issue, which will be published about the end of August, will be **August 9, 1996.**

Radiophobia article lacks focus

Ed. Note: The following letter has been edited for length.

The Editor

The paper by Jerry Cuttler in the recent issue of the CNS Bulletin (Vol. 17, No. 1) reflects the concern and frustration that many in the nuclear industry must feel. The topic of "radiophobia" appears to include a vast nexus of historical, sociological, political, technical and probably personal agendas. (In this connection, I am somewhat surprised that the author did not make reference to the book "Nuclear Fear: A History of Images" by Spencer Weart.)

The essence of the issue of radiophobia is far from clear to me, and in its details is likely to be extremely complex and very confusing. The Bulletin article appears not to acknowledge this, but I'm afraid that the author's case, as presented, has other (and more serious) faults.

First, the article suffers from a lack of focus. The main thesis seems to be that a threat to the future of the nuclear industry arises from a general public infection by radiophobia. However, it isn't clear whether the actual root of the problem is (a) the mere existence of this radiophobia among the general public, or (b) the existence of the linear dose-response model. One is justified in asking some basic questions.

What exactly is meant by "radiophobia"? What is the specific problem that the author is trying to attack? What is the plan for this attack? (It is not explicitly stated anywhere, but the assumption seems to be that if we get rid of the linear hypothesis, then radiophobia will fade away all by itself, thereby ushering in the golden age. This outcome seems to me to be something less than a sure bet.)

Second, the author has not taken sufficient care, in my view, to avoid the special pleading trap. When it is in someone's interest to have a certain outcome occur, then that "someone" should take extra care to state his or her interests, to try to take into account everyone else's real or perceived interests, and to be very careful in the way the case is presented.

Nobody in the nuclear business would doubt, I think, that reactors have been built and are being operated because they are expected to provide an excess of benefit over risk to the public. Equally, few in the nuclear business would continue to support the technology if these expectations were proved drastically wrong, for example if it were shown that nuclear technology provided a very poor benefit/risk ratio.

The article projects, to me, a greater concern for the nuclear industry's special interests, and much less concern for, or even understanding of, the common societal interest. Great care has to be taken not to leave the impression that, despite an ostensible concern for societal interests, one is actually pleading only in favour of a special interest. Avoiding this trap goes far, far beyond just choosing the appropriate words.

Two examples may help to illustrate what I mean.

The first sentence of the abstract sets the wrong tone entirely. "Canadian nuclear technology is threatened by radiophobia." Very few people out there care about Canadian nuclear technology. Why should they? They have to care about their jobs, the cost of living, their kids' education and scores of other issues that affect or may concern them. Something they might care about, however, is the possibility that radiophobia may be foreclosing an energy option that could save them money.

In the second paragraph, an even more damaging statement appears. "Today's youth will form tomorrow's governments. Would we expect them to cherish and foster our nuclear heritage?" [Emphasis added.] The obvious question here is: Who is "them" and who is "us"? A not unreasonable answer, to an outsider, is that "us" is the nuclear industry special interest.

Third, there is something oddly incoherent about the way the article unfolds. First of all, a case is made as to why the linear dose-response model is inadequate. Following from that, there is a call to the scientific community to take action to rectify this situation. Unfortunately, the linear model was developed by the scientific community, by the ICRP and various other bodies. Canadian scientists have contributed to these efforts. Is it these scientists who should now rise up against the linear model, and if so, why haven't they done so earlier? If scientists other than these experts are being urged to action, then the whole case may have a deep credibility problem.

Fourth, part of the call to action involves an appeal to inform or educate the public. At the very best, this kind of statement is somewhat condescending. Personally, I feel that any such crusade to "inform" or to "educate" the public probably won't work. Having worked for a time in AECL's public affairs department, I have some idea whereof I speak. Let us remember that most of us work for them. We may have specialist information that they lack. But in any attempt to influence them, the case we make should be on the basis of one group of human beings talking to another, and as human beings they are every bit our equals.

Fifth, and last, there are several places where unfortunate phrasing is used. My preference would have been to avoid the quote referring to the Bible and Shakespeare. This only narrows and deflects the thrust of the argument, shifting it into unnecessarily partisan domains. The abstract talks about a "misuse of the linear dose-response model", and later there is a reference to "the inappropriate use of the unsubstantiated linear, no threshold dose-response hypothesis". Anyone who sees this as a professional accusation may react rather violently to these statements. The author seems to be expressing impatience that the apparent simplicity of the issues at the root of radiophobia has gone unnoticed, when he makes the statement "You don't need a university degree to understand it". Then there is the very inflammatory statement "Many thousands of abortions were performed needlessly". I'm not sure what impression other readers get from this. Mine is not at all pleasant.

These criticisms all seem very negative, but I hope and I believe that they could all be applied positively. Dr. Cuttler has produced an article that is, at bottom, hopeful and upbeat, directed toward viewing nuclear technology in the light of its benefits, and not dwelling only on its perceived risks. His case could be made still more forceful, more positive, more appealing and more convincing.

Keith Weaver

Biological effects of low doses of ionizing radiation - fact or scare?

The Editor

The UNSCEAR article in the Winter 1996 issue of the CNS Bulletin provides to readers a perfect example of the basis for radiophobia.

Does the 1994 UNSCEAR report really provide "a full picture"? The article points to plenty of theory based on many assumptions, but what does it all prove? Does any of this theory fit the data accumulated over the past century? Do we really understand the mechanism of radiation oncogenesis? Do we have a scientific basis on which to predict to the public the number of excess fatal cancers that will result from exposures to low-level radiation? This article provides no confidence that UNSCEAR has achieved this. Only crystal-ball predictions are made.

The article is replete with fuzzy words: "could, can, if, should, may, could kill, it is believed to be, it is presumed, probably, suggests, assumes, plausible, ..." The description of stochastic effects is pure theory; there is a lack of conclusive evidence.

It is certainly pleasing that the 1994 report finally recognizes that there are efficient repair mechanisms at work and that DNA mutations can be reduced by radiation because of stimulation of the repair mechanisms. Unfortunately, it does not go on to address the net positive effective observed at low doses. It is certainly reasonable to expect that repair might not be error-free, but could we not expect that stimulated repair mechanisms actually repair more than what was damaged by radiation? After all, there are spontaneous mutations and mutations by other causes (e.g. chemicals, etc.) that are being continuously repaired. There is no mention of the evidence of less cancer in populations in areas of high natural radiation due to altitude, radioactive rock and radon emissions, where more cancer was predicted.

It is appropriate to make plausible assumptions to create a theory that might explain data, but the theory must be validated by all of the existing data and not be contradicted by any new data before a scientist goes public to predict excess fatal cancers from low-level radiation.

The article states that the most comprehensive source of primary epidemiological information is the Japanese survivors/ "life span study" of 86,000 individuals. This data relates to high-level, not-well-defined, acute radiation doses. On the other hand, there is a US Department of Energy study on 700,000 nuclear shipyard works (NSWS) that was completed in 1991. It reported a relative risk of 0.76 (95% confidence interval: 0.73, 0.79) for workers with more than 50 mSv (5 rem) of occupational exposure. This data is more relevant to the issue.

Did UNSCEAR examine the NSWS data? The article states that "epidemiological studies on the effects of low-does-rate exposure undertaken for occupational exposures have shown conflicting evidence:. The NSWS results are certainly in conflict with the LNT model. Did UNSCEAR examine Professor Cohen's test of the LNT theory for inhaled radon decay products? The article states that such "studies on adaptation have been of lower statistical power" and "do not provide evidence of an adaptive response". This is certainly a sweeping statement. The "lack of epidemiological data" is the justification for UNSCEAR mkaing risk assessments, for low-level radiation, based on extrapolations using theoretical assumptions from plausible models, with fudge factors of "considerable uncertainty".

Why are people making predictions about a hypothetical adverse health effect that has not data? There are so many other clean and present health threats; it is difficult to understand why low-level radiation is receiving any attention at all by the authorities.

The section, Outlook, makes no sense. First it states that "thanks to the work of UNSCEAR, the biological effects of ionizing radiation are better known that those of many other chemical and physical agents affecting human beings and the environment,... there are still many unanswered questions... in relation to the effects of low radiation doses". Then it states, "One problem is the lack of empirical evidence. ...evidence of the effects of low-level radiation does not exist and will probably not be obtainable for a long time."

So, all UNSCEAR has provided are unsubstantiated assumptions, models, hypotheses, predictions, etc. and no prospect of anything better for a long time. This nonsense must be stopped. This is the cause of the fear of radiation that is threatening the future of nuclear technology. By our inaction, we are allowing it to continue. When will the stakeholders in nuclear technology begin to take effective measures?

Jerry Cuttler

CLARIFICATION

The editor's preamble to the letter in the last issue (CNS Bulletin, Vol. 17, No. 1) from Terry Jamieson on "The Folly of Russian Molybdenum" referenced an article in the Ottawa Citizen which stated that the Ottawa firm of Candesal Inc. was negotiating with a Russian organization for the supply of Molybdenum 99. (Technetium 99m which is used extensively in nuclear medicine is a daughter of Molybdenum 99.)

Mr. J. J. Blais, the president of Candesal Inc. has informed the CNS Bulletin that neither Candesal Inc. nor he is involved in any negotiations with Russia.

The company pursuing the Russian source for Molybdenum 99 is RCT (Russia Canada Technologies) which was formed by two persons who are associated with Candesal. Mr. Blais states that he has no association with RCT.

Biological effects of low doses of ionizing radiation - fact or scare?

The Editor

Re: Article on "Overcoming the Fear of Radiation: The Key to the Golden Age of Nuclear Technology"

Dr. Cuttler's call for action on the issue of health effects from low level radiation needs to be given very serious consideration. Canada's nuclear technology and the CANDU program are definitely in jeopardy. One of the main reasons is the general concern about health effects, particularly cancer due to the low level radiation.

The application of the linear dose-response model leads to the prediction of fatal cancers resulting from low level radiation even at natural background levels. This model allows the anti-nuclear group and some of the media to make exaggerated predictions of fatalities which are clearly questionable as Dr. Cuttler's article points out. This practice was evident during the recent media coverage of Chernobyl's 10th anniversary. For example, a CBC foreign correspondent (reporting from Kiev) stated that 160,000 fatalities are being predicted as a result of the accident.

In addition, the linear dose-response model is being used to justify expenditures of large sums of money to minimize dose from low level radiation. One must question these expenditures for very little benefit, particularly when health care budgets are generally being cut.

I strongly recommend that the CNS take up the issue presented by Dr. Cuttler. There is an immediate need to challenge the application of the linear dose-response model. The real facts about the effects of low level radiation need to be communicated to the general public.

Action is required now before we lose a great technology.

P.R. Burroughs

Russian Molybdenum – A Response

The Editor

A letter appeared in the Winter 1996 (Vol. 17, No. 1) of the CNS Bulletin under the title of "The Folly of Russian Molybdenum". We would like to offer the following observations.

For many years Russia has been producing and supplying radioisotopes into both domestic and international markets. Successive Russian governments have, by policy and action, taken steps to ensure the continuity of their supply to those markets and the Russian Federation is committed to being a long term player in the supply of radioisotopes. Recognizing the importance of Russia's involvement in various peaceful applications of nuclear technology, Canada, as well as other western governments, has signed an accord with Russia, "stressing interest in long term cooperation and joint action in the world markets in using the scientific, engineering and industrial potential of the parties".

Russia Canada Technologies Incorporated (RCTI) was formed within the spirit of this Canadian government initiative to participate with Russia in the production and distribution of their isotope products. In the interest of maintaining a strong Canadian position in the international marketing of radioisotopes, RCTI has approached Canadian industry offering Russian molybdenum (Mo99) as one of the options for increasing security of supply.

The major concern of all users of this strategic isotope is security of supply. As note by Mr. Jamieson [in the referenced letter] AECL cannot guarantee a continuous supply to Canadian industry without a replacement for the NRU reactor. One might well ask what would be the impact on Canada's image if this ageing reactor, which is Canada's sole source of supply at the present time, were to shutdown again as it did in 1991 but, this time, without NRX to maintain production of Mo99. The ability to guarantee continuity of supply by the Russian producers is much higher due to the multiplicity of reactors producing, and capable of producing, radioisotopes.

We agree that there is a very real danger to the Canadian nuclear industry. But that danger is in not recognizing the fundamental weakness and instability of the current situation. We believe that to achieve stability, wholly within the Canadian industry, will require completion of the Maple X 10 reactor, construction of a second Maple reactor as a backup source, and the construction of facilities for the long term storage and treatment of Mo99 production wastes. It is not unreasonable to conclude that the large capital investment required to achieve stability under this scenario will cause Mo99 prices to increase substantially, and that the time required to secure the financing and complete the construction of the required facilities will preclude resolution of the current instability problem for several years.

It seems clear that an alliance between Canada and Russia producers is crucial to guarantee continuous near term security of supply. It also offers the only real opportunity to stabilize prices and allow Canada a continued preeminent position in the marketplace.

J.A. Belanger
President
RCTI

CNA/CNS Annual Student Conference

Ed. Note: *This year's CNA/CNS Student Conference was very well organized and run thanks to the efforts of two doctoral candidates, Sadok Guellouz and Mohamed Lamari. The fact that both are involved in the Ottawa CNS Branch (Lamari is the Chair) is further evidence of their commitment to the nuclear field and their ability to organize a very demanding schedule. The following is basically their report. The three winning papers are reprinted in a Special Supplement to this issue.*

All aspects of the event went off smoothly and on time. The quality of the papers presented and the confidence demonstrated in the presentations speaks highly of the calibre of students pursuing nuclear science in Canada and of the capabilities and dedication of their instructors ands supervisors. Unfortunately, only a few universites were represented and none west of Ontario (despite the travel subsidies offered through the organizers).

In recognition of the high standard of the presentations the three winning papers are reproduced as a Special Supplement in this issue of the CNS Bulletin.

The following account of the Conference was prepared by Sadok Guellouz with the co-operation of the chairpersons of the various sessions which were organized on a topical basis.

OVERVIEW

On Friday and Saturday, March 15 and 16, 1996, some seventy students, professors and nuclear industry professionals, from across Canada, were gathered in Colonel By Hall, the engineering building of the University of Ottawa, to participate in the 21st Canadian Nuclear Association and Canadian Nuclear Society (CNA/CNS) Annual Student Conference. University Students from undergraduate, masters and doctorate programs had the opportunity to present their research work in the fields of nuclear science and engineering. Twenty-seven out of the twenty-nine papers submitted were presented. All contributed papers have been compiled and published in a bound conference proceedings, made available to attendees at the time of the conference (and available from the CNS office).

This year's conference, hosted by the Ottawa-Carleton Institute for Mechanical and Aerospace Engineering, was co-chaired by Mohamed Sadok Guellouz, University of Ottawa, and Mohamed Limayem Lamari, Carleton University.

In addition to the technical presentation sessions, the Conference featured a full-day Technical Tour of AECL's Chalk River Laboratories (on Thursday), an Invited Talk and a Banquet. Nineteen students took part of the technical tour, arranged by Ima Kalos and her team of the Chalk River visitor's centre. According to the participants, the tour was well organized and very informative.

The Invited Talk, entitled "The CANDU Program", was delivered, on Friday morning prior to the opening of the conference, by Dr. Jerry Cuttler, a manager at AECL Sheridan Park and President of the CNS, to an audience of local graduate and undergraduate students and conference participants. The talk, designed to provide an overview of the Canadian nuclear program, attracted a large audience and exposed new students to the technology of nuclear power plants.

The Conference Banquet was held on the evening of Friday, March 15, in conjunction with the annual dinner of the Ottawa branch of the CNS. The guest speaker for the banquet was Mr Jon H.F. Jennekens, former president of the AECB, former deputy director general and head of the safeguards department at the International Atomic Energy Agnecy and currently chairman of Ontario Hydro's Technical Advisory Panel on Nuclear Safety and member of the Canadian siting board for ITER.

In the coffee-break area, i.e. the lobby in front of the main conference auditorium, three information booths were set. The first displayed literature, gathered by the conference organisers, from the CNS, the CNA, AECL, Nordion and Hydro-Québec. The other two, consisted of booths set up by the Atomic Energy Control Board and the organisers of next year's conference in Fredericton, New Brunswick.

Technical Sessions: Chairpersons' Reports

During the two days of the Conference, attendees listened to high calibre presentations covering a large spectrum of topics in nuclear science and engineering. These are summarized below, based on reports submitted by the session chairs.

Session 1: Nuclear Safety Chairperson: Dr. J.R. Rizni, AECB

Four papers were presented in this session. Sean Marshall, graduate student of McMaster University presented a paper on Historical Safety of Nuclear Submarines in Russia. An attempt was made to examine the performance records of submarine reactors in general, and those of the Russian reactors specifical-

CNS President Jerry Cuttler presents Pamela Tume of the Royal Military College with the first prize in the Doctoral category at the CNA/CNS Students Conference in Ottawa, May 16, 1996.

ly, to determine whether or not they are suited to serve as electrical power plants. In conclusion, Sean suggested that the conversion of existing nuclear submarine reactors to serve as civilian power stations does not appear to be a safe alternative source of power.

The second paper, by Captain Roger Hugron, graduate student at the Royal Military College of Canada, dealt with the Consequences of a Nuclear Submarine Reactor Accident. In his research, Roger analyzed a hypothetical large break LOCA aboard a nuclear powered vessel and its possible consequences, in terms of individual doses of fission products released to the environment. Preliminary results show that even if there is a large quantity of activity in the fuel at the time of a specific accident, little activity will be released to the atmosphere because of a combination of engineered safety barriers and physical hold-up processes.

Ka Hing Lin, graduate student at the University of Toronto presented results of a research on the Partition Coefficients of Iodoalkanes. The partition coefficients have been used extensively in the environment chemistry to describe the interfacial distribution of chemicals. Ka Hing developed a novel experimental procedure for dynamic measurements. Data on the partition coefficients of several iodoalkanes were presented and compared to the results of other authors. These indicated that the proposed method gives an accurate measurement of the partition coefficients, but additional work is necessary in refining the methodology.

Pamela Tume, Doctoral student at the Royal Military College of Canada, presented a paper on the Assessment of the Cosmic Radiation Field at Jet Altitudes. The study involved a survey of military pilots during normal flight duties, to determine their annual total dose equivalent. The latter was found to be below the current limit for the public and may exceed the ICRP-60 recommended limits.

Session 2a: Iodine Chemistry Chairperson: Dr. D.R. Wiles, Carleton University

Iodine occupies a unique position among the radionuclides produced in nuclear reactors, not only because it is more mobile than most other elements but also because it furnishes perhaps the most hazardous radionuclides both in the short term (131I) and in the very long term (129I). As a consequence, it is particularly important that we come to understand its behaviour and its control in the environment. A series of five research papers, all from the University of Toronto, deal with several aspects of the properties and behaviour of iodine compounds.

The first paper in this series, The Destruction of Iodate in Gamma-Irradiated Solutions, by Christine Gallagher, dealt with the radiation chemistry of iodate ions under simulated reactor conditions. Two papers, The Effect of Chemical Reaction of the Mass Transfer of Iodine, by Juliette Ling and The Effect of pH on Iodine Volatilization Rates, by E.J.Panyan, dealt with mass transfer processes, as influenced by chemical reactions. Two further papers, The Retention of Iodine in Stainless Steel Sampling Lines, by Tutun Nugraha and Extraction of Iodine from Environmental Samples, by Mark Ho treated aspects of the chemical analysis and monitoring of iodine activity.

These papers all presented preliminary results of work in progress, and it may be expected that each of them will provide information and understanding important to the control of these fission products.

Session 2b: Nuclear Materials Chairperson: Dr. P. Frise, Carleton University

Five papers were presented in this session beginning with a discussion of Passivation of Stainless Steels in Simulated Reactor Coolants by Daniel F. Basque of the University of New Brunswick. He examined the rate of corrosion of two grades of stainless steel in the presence of magnesium and zinc additives and found that both additives helped to reduce the rate of oxide formation but that the magnesium was about twice as effective, at least with the AISI 316L stainless grade.

The second paper was by Haroon I. Sheikh of the University of Toronto and was entitled: Location of Alloying Elements in Oxide Films on Zirconium Alloys. Mr. Sheikh used several advanced microscopic techniques such as TEM, EDX and X-ray mapping to locate the particles of iron, chromium and nickel in the oxide film on Zircalloy-2 samples.

Darren D. Radford presented the third paper in the session. Mr. Radford's paper, entitled: Experimental Technique for Testing CANDU Fuel Channel Components at high Rates of Strain was a description of the tensile split-Hopkinson bar method of loading a specimen at a very high strain rate. The original apparatus was built at Carleton University and another has been built at AECLs Whiteshell labs to carry out this work on irradiated specimens of fuel channel material.

The fourth paper was presented by Kim Jones, also of Carleton University in Ottawa. Mrs. Jones' work on non-destructive testing of fuel channel materials was presented in her paper: Electrical Non-Destructive Testing of Zr-2.5Nb Specimens. She described the Direct Current Potential Drop (DCPD) method of crack measurement and presented some results of her test program including some tests at high temperatures to simulate actual reactor operating conditions.

The final paper in the session was given by Mr. Phillip Tan of the University of Toronto and was entitled: Fate of Heavy Metals and Trace Elements in Residential Composters. This was a very interesting and timely study of how backyard composting concentrates the heavy metals that are used in vegetable fertilizers into the soil which comes out of the composter unit. The study showed that the soil is fairly high in these undesirable substances. It was noted that the environmental community did not want this study done since they felt that it might decrease the appeal of composting to the average citizen.

Phillip's very fine effort was recognized by an Honourable Mention in the Awards Ceremony.

Session 3: Simulation chairperson: Dr. W.J. Garland, McMaster University.

The simulation session consisted of two papers on enhancements to the 3D Reactor Code, DONJON, under development at Ecole Polytechnique de Montréal, and two probabilistic studies using the Monte Carlo code, MCNP.

Catalin Ovanes, Master's candidate at Ecole Polytechnique, presented on Xenon-135 modelling in DONJON. Steady state has been implemented and transient modelling is underway.

Michaela Ovanes, Master's candidate at Ecole Polytechnique, discussed SDS1 implementation in DONJON. Again, steady state is complete and work is proceeding on the transient mode.

Martin Pierre, Master's candidate at the Royal Military College, reported on a rather detailed modelling of LEU SLOWPOKE-2 using MCNP 4A. In particular, the temperature reactivity coefficient was studied, giving much better agreement to experimental data than previously achieved with deterministic codes.

Luc Gingras, an undergraduate student at Université Laval, discussed the MCNP simulation of collisions of heavy ions.

All papers were of high calibre, the question periods were vigorous.

Session 4: Thermalhydraulics Chairperson: Dr. S. Tavoularis, University of Ottawa.

The Thermalhydraulics session included three papers. The first two were experimental studies, while the third one was a numerical investigation.

Serge Bédard, of Ecole Polytechnique de Montréal, presented experimental results on counter-current flow, of air and water, and flooding in a test section containing a vertical run and a horizontal run in which an orifice was placed. The study examined the influence of the position, with respect to the elbow

Chief Judge Terry Rogers and co-chairman Sadok Guellouz and Mohamed Lamari relax during a break at the CNA/CNS Students Conference in Ottawa, March 16, 1996.

between the vertical and horizontal runs, of various sizes orifices on the flooding limit and the partial liquid delivery.

Geng Chen, of the University of Ottawa, reported preliminary test results of an on-going experimental study of Critical Heat Flux (CHF) in a dumb-bell shaped tube. This geometry, which consists of two subchannels interconnected via a narrow gap, is used to investigate the effect of gap size on CHF.

The third paper, entitled Two-Dimensional Modeling of a Magnetohydrodynamic Flow in the Cooling Channels of a Nuclear Fusion Reactor was presented by Alex Kwan of McMaster University. It discussed the effect of a magnetic field on the flow of a liquid metal and the heat transfer.

Session 5: Radiation Chemistry / Radiation Instrumentation and Dosimetry Chairperson: Dr. J.F. Lafortune, SAIC-Canada

Five papers were presented. In Radiation Processing of Nitrocellulose, Michelle Bickerton and Dan Murphy, Royal Military College, discussed the potential of irradiating nitrocellulose polymers as a method of reducing the hydrogen content of explosive grade nitrocellulose. They found that exposure to thermal neutrons is effective in lowering hydrogen content.

Hilary Harris, Royal Military College, presented a paper titled Radiation Effects on Epoxy Resins, where she discussed the effects of various types of radiations on the strength of epoxy adhesive resins. Her experiments show a definite impact of irradiation, dose rate and time of exposure with respect to curing on the strength of epoxy adhesives.

In Radiochemical Study of the Interaction of Zinc and Cadmium with Fly Ash under Leaching Conditions, James Rodgers, University of Toronto, used neutron activation analysis to study the leaching dynamics of metals in incinerator ash, in order to examine the potential environmental impact of incinerating waste prior to landfilling. The results of his experiments show that a high pH is a dominating factor in the ability of municipal solid waste to bind metals.

Sophia Wang, University of Toronto, then presented a paper on the Analysis of Arsenic and Uranium in Environmental Samples from a Low Level Radioactive Waste Management Facility. Using epithermal neutron activation analysis, she was able to produce a reliable mapping of the distribution of contamination in samples of vegetation, soil and water at the Port Granby Waste Management Facility.

The final paper on the Calibration of the Eberline ASP-1 Portable Hand Held Survey Meter described the work done by Brian Corse, Marnie Ham and David Sims, Royal Military College, to design, test and utilize a calibration rig and facility for a radiation detection instrument to be widely used by the Canadian Forces. The calibration technique developed uses a 120 Ci Cs-137 source and respects all AECB requirements for calibration and safety.

Awards

A five-member judging committee, chaired by Dr. J.T. Rogers (Carleton University) and composed of Dr. J.C. Cuttler (AECL and President of the CNS), Dr. T. Rummery (former President, AECL Research), Dr. F. McDonnell (AECL) and Mr. F. Boyd (former AECB) reviewed all presentations. They had a difficult task selecting the Award winning papers. At the closing of the Conference, Awards were presented for the Best Communications (reflecting both technical content of the paper and the presentation) in each of the following categories, Undergraduate, Master's and Doctorate. The First prize in each category consisted of a cheque and CorelDRAWTM6 software package, while the second prize included a cheque and a CD-ROM. The Honourable Mention prize was a CD-ROM. All awarded software were a courtesy of Corel Corporation.

The results of the Best Communication competition were as follow:

Doctorate Category:
1st Prize: Pamela Tume,
Royal Military College of Canada.
Masters Category:
1st Prize: J.R. Martin Pierre,
Royal Military College of Canada.
2nd Prize: Serge Bédard,
Ecole Polytechnique de Montréal.
Undergraduate Category:
1st Prize: Mark D. Ho, University of Toronto.
2nd Prize: Luc Gingras, Université Laval.

• **Honourable Mention:**
Phillip Tan, undergraduate, University of Toronto.

Sponsorship

The following organizations were sponsors of the 21st CNA/CNS Annual Student Conference:

- Canadian Nuclear Association
- Canadian Nuclear Society
- Atomic Energy of Canada Limited
- Ontario Hydro Nuclear
- Natural Resources Canada, NRCan UNEB
- Corel Corporation
- Science Applications International Corporation, SAIC-Canada.
- Canatom Incorporated
- Scintrex Limited
- Uranium Saskatchewan Association
- Graduate Students' Association des Étudiant.e.s Diplômé.e.s (University of Ottawa).

Geological Disposal Concept Hearings

The month of March saw another act in that continuing nuclear road show - the hearings on Atomic Energy of Canada Limited's concept for the disposal of spent fuel in deep geologic caverns. The hearings are being conducted by a panel officially called the "Nuclear Fuel Waste Management and Disposal Concept Environmental Assessment Panel".

This round of hearings is reviewing the Environmental Impact Statement and associated documents that AECL submitted last year. The Panel had previously sought comments on the adequacy of the EIS and concluded, despite a number of submissions pointing out inadequacies (including one from the Panel's own advisory Scientific Review group), that the EIS was sufficiently complete to permit this set of hearing to proceed.

These hearings are arranged in three phases. Phase I, just completed, focused on the broad societal issues related to the long-term management of nuclear fuel waste. Phase II will focus on technical aspects of AECL's concept of geologic disposal. It will be held in Toronto, June 10-14 and 17-21, with two days, June 27-28 devoted to environmental, health and socio-economic impacts. (Advertisements announcing Phase II appeared in daily newspapers in early May.) Phase III which will be held in the fall of 1996 will consist of community visits in New Brunswick, Quebec, Ontario, Manitoba and Saskatchewan to give participants an opportunity to provide final opinions and views on the safety and acceptability of AECL's geologic concept and any other issue relevant to the Panel's mandate.

Following are accounts of the first two weeks of Phase I hearings, extracted from UNECAN NEWS, the monthly industry newsletter, thanks to publisher Ken Smith.[1]

WEEK 1

The federal Environmental Assessment Review Panel began Phase I of its public hearings on AECL's concept for the geological disposal of used fuel on March 11 in Toronto. The schedule for the Phase I hearings was:

- March 11-15 and March 25-29 in the Toronto area;
- April 29 and 30 in Thunder Bay;
- May 1 in Sudbury, and May 2 in the town of Chalk River.
  (subsequently a second day was added in Chalk River)

The members of the Environmental Assessment Panel are:

- Blair Seaborn, Chairman: former Deputy Minister of Environment Canada;
- Denis Brown: Consultant Health Physicist, Saskatchewan;
- William Fyfe: Professor, Department of Geology, University of Western Ontario;
- Mary Jamieson: President, Economic Development, Canadian Aboriginal Women;
- Louis Lapierre: Professor, Department of Biology, University of Moncton;
- Louise Roy: Environmental consultant, former member of the Quebec environmental assessment organization;
- Pieter Van Vliet: Consulting Mechanical Engineer, Saskatchewan;
- Lois Wilson: Chancellor of Lakehead University; former Moderator, United Church of Canada.

Phase I of the hearings is dedicated to receiving submissions on general societal issues. For this phase, AECL and Ontario Hydro were not in the role of proponents, but are merely two of the many contributors. Both AECL and Ontario Hydro decided that their staff should avoid debating with the numerous anti-nuclear activists. Both companies felt that little would be gained by trying to argue with the opponents of the disposal concept during Phase I. For better or worse, this placed the representatives from the Canadian Nuclear Society and the Canadian Nuclear Association in a position of having to ask clarifying questions of the opponents, or put forward alternate positions. However, even these organizations kept their interventions to a minimum.

The situation will be different in the second and third phases, when AECL and Ontario Hydro will be sitting as proponents. As such they will be in a position where they can be questioned directly by the intervenors, but can (in return) put questions to those making submissions.

The Chairman opened the hearings by stating that each presentation would be limited to precisely 20 minutes, at which time their microphone would be turned off and transcription would cease. This rule was rigidly applied, and caused some of the unprepared presenters to be cut off, much to their dismay. Each submission was followed by a ten-minute question period. However, the Chairman sometimes relaxed on the ten-minute limit if there were many individuals wishing to raise questions.

In the first week, 50 presentations were received by the Panel:

- proponents and supporting organizations - 4
- government departments and agencies - 5
- environmental and activist organizations - 18
- individuals or neutral organizations - 6
- aboriginal groups - 6
- specialist speakers invited by the Panel - 11

In addition, the Panel arranged four "round table" discussions, two of which involved forming into four to six small groups with a mixture of individuals in each group. These "round tables" were not very useful except that they permitted the public (primarily the activist organizations) ample opportunities to express their points of view.

About 140 people were in attendance the first day, but by the end of the week the number had dropped to about 30. The first day started with a positive presentation by Natural Resources Canada. Two of the NRCan statements were: "The implementation of an acceptable disposal concept would further protect the health of Canadians and ecosystems, and demonstrate that nuclear development is sustainable development." "By making provision for disposal today, we ensure that this generation, which receives the benefits of nuclear development, also absorbs its costs."

Norm Rubin, of Energy Probe, asked how the Canadian government could make such a definitive statement, when it had previously asked the Panel to evaluate the concept. The government representatives responded that plans have to be made for the eventuality that the Panel will find the concept acceptable.

This was followed by relatively straightforward presentations from Ontario Hydro and AECL, outlining their responsibilities, activities, and conclusions in the evaluation of the deep disposal concept. The Atomic Energy Control Board and Environment Canada indicated that they believed that the concept could be acceptable, even though they considered that the documentation provided by AECL contained numerous detailed deficiencies and therefore did not prove that the concept was acceptable. Various intervenors questioned how they could come to an "acceptability" conclusion in the absence of an acceptable EIS.

The Canadian Nuclear Society outlined the continuing need for nuclear power, summarized the radiation exposures and health effects of the proposed concept, and made comparisons with other risks faced by society. The CNS made a strong recommendation that the Panel should find the concept to be acceptable and should recommend that the government proceed with the siting process.

Five aboriginal groups expressed frustration that their communities have not been adequately involved in consultations during the concept evaluation phase. Some requested that the Panel should halt proceedings until AECL had properly consulted with aboriginal representatives. They also requested that funding be provided to enable them to undertake their own review. They were not satisfied with AECL's position that full consultation would occur during the siting phase.

Four environmental or activist organizations (Northwatch, Saskatchewan Environment Society, the Inter-Church Uranium Committee, and the Canadian Coalition for Nuclear Responsibility) presented critical comments which contained a number of common points:

- The Panel was criticized for not submitting a deficiency report to AECL, particularly in view of the critical comments contained in the report from the Scientific Review Group (SRG).
- The Panel was criticized for deciding to proceed with Phase I of the hearings before obtaining an AECL response to the deficiencies identified by numerous intervenors last September.
- The Canadian government was criticized for not proceeding with the review of the future of nuclear power in Canada, as promised when the terms of reference for this Panel were established.
- The Panel was urged to seek expanded terms of reference, to permit it to review the need for nuclear power.
- The Panel procedures were criticized for not permitting cross-examination of witnesses, as would be the case under the Ontario environmental assessment procedures.

The Panel Chairman did not accept that these issues would hinder the deliberations of the Panel, and did not offer to take any action. Nevertheless, these intervenors have made it clear that they have no confidence in the current review process, and will not be satisfied with the Panel's conclusions, whatever they might be.

Throughout the week, the anti-nuclear intervenors also made various other points, including:

- "There is no satisfactory solution for the management and disposal of used fuel."
- "The world would be better off without nuclear reactors or their waste."
- "There should be a phase-out of nuclear power, to minimize the creation of more nuclear waste."
- "As a concept proponent, AECL has no credibility."
- "AECL's foreign CANDU sales activities may lead to the return of used fuel for disposal."

Late in the week, the AECB outlined the method used to determine risk (probability x consequence). The AECB risk limit, expressed as an annual probability of fatal cancer or serious genetic defect, is one in a million, or 10-6. This leads to a radiation exposure limit of 0.016 mSv/a. For comparison, Ontario Hydro provided a table of background radiation levels across Canada:

Background Radiation Level (mSv/a)

Vancouver	- 1.2	Edmonton	- 1.8	Regina	- 2.6
Winnipeg	- 3.2	Toronto	- 1.6	Montreal	- 1.4
Halifax	- 2.2				

On Friday, Energy Probe recommended that the AECB should define the acceptable limit as a lifetime risk of cancer of 10-6, as opposed to an annual risk of 10-6. Energy Probe calculated that this translated into an annual radiation dose limit for the general public of 0.09 _Sv/a. This led to some amusement because such a limit would be about 18,000 times less than the background level in the Toronto area.

One of the invited speakers made an interesting point by asking us to look back one or two hundred years. The issues that society faced then were completely different. Thus, it is impossible to try to guess what the situation will be in 200 or 500 years into the future. For example, today's concern about radiation induced cancer might be totally eliminated by then. It is quite likely that the future generations will consider today's discussion to be quite humorous. Thus, we should not place too much emphasis on future safety concerns. We should make the best possible decision using today's safety standards.

WEEK 2

The second week of public hearings on AECL's concept for the geological disposal of used fuel was held by the federal Environmental Assessment Review Panel from March 25 to 29 in the Toronto area. Much of the time was taken up with issues related to siting and implementation of a disposal facility. There were 33 presentations:

- proponents and supporting organizations - 8
- government departments and agencies - 4
- environmental and activist organizations - 9
- individuals or neutral organizations - 8
- aboriginal groups - 1
- specialist speakers invited by the Panel - 8

The Panel continued to rigidly apply the 20-minute time limit for presentations.

In addition, the Panel arranged five further "round table" discussions.

Siting Process

The first three days were allocated to a review of AECL's proposal for the siting process, and the experiences with previous siting processes for low-level radioactive wastes and other toxic waste facilities. In general, the representatives of activist organizations argued that the previous siting processes in Canada have been complete failures. On the other hand, those directly involved in these siting processes reported that, in spite of various difficulties, they were satisfied that the process had been reasonably successful. Some of the examples which were discussed included:

- the search for a disposal site for the historical low-level wastes that exist in the Port Hope area;
- the search for a solution to the cleanup and disposition of the radium-contaminated soil that was discovered in the Malvern community in Scarborough;
- the search for sites for toxic waste facilities in Alberta and Manitoba;
- the siting of various Ontario Hydro facilities, including discussion with aboriginal groups regarding northern hydro-electric facilities.

In addition, three invited speakers outlined the experience with the siting of radioactive waste sites in Sweden, in other European countries, and in the USA.

The representatives from the McMaster Institute for Energy Studies presented an interesting submission. Their main point was that concept acceptability is as much dependent on social acceptability as on technical feasibility. They argued that AECL had concentrated too much on technical detail in its EIS, while paying insufficient attention to social issues. (This point was analogous to comments made during the presentations regarding the siting problems being experienced in Sweden and the USA.) It is expected that AECL will respond to these criticisms later in the hearings.

Transportation

Transport Canada outlined the regulations covering the shipment of radioactive materials, and Ontario Hydro described the equipment developed for the shipment of used fuel. There are currently about 20 shipments of used fuel per year, primarily from the nuclear stations to Chalk River.

The anti-nuclear groups then attacked all aspects of the shipment of used fuel: Why is Transport Canada not notified of each shipment? Why are communities not notified? Will school buses and fuel shipment trucks be on the road at the same time? What about terrorist attacks? What security provisions will be provided? Someone even asked if the Nuclear Liability Act would apply in the event of an accident.

Petter Prebble, the former NDP MLA from Saskatchewan asked whether the principle of community voluntarism would apply to communities along the shipping route — i.e., would they be able to vote on whether or not to accept the transportation proposal. The activist groups liked this idea because it would only take opposition from one community to veto any disposal proposal. Ian Wilson (CNA) pointed out that if this philosophy was applied to all truck and train transport in Canada, the whole country could be shut down — nothing would move.

Implementing and Management Agency

Ken Nash of Ontario Hydro pointed out that OH owns 90% of the used fuel and will provide 90% of the funding for its disposal. the utility proposes to take the lead role in the management and operation of a disposal facility, subject to federal government policies and AECB regulatory requirements. A possible alternative arrangement would be an organization formed by the three nuclear utilities. He said that Ontario Hydro does not agree with the transfer of responsibility to a separate government agency because the utility would not be able to ensure that the available funding for disposal would be used in a timely and cost-effective manner.

Various concerns were expressed by intervenors about an organization led by Ontario Hydro, such as:

- the proposed advisory committees would not have authority to ensure environmental and social issues were considered;

- it is too tempting for the provincial government of the day to interfere with the operation.

Paul Brown of Dalhousie University recommended that a single federal agency be created with broad representation on its Board of Directors - from federal and provincial governments, industry, environmental groups, aboriginals. He recommended against a multi-governmental agency because of conflicting priorities. He further recommended that the implementing agency NOT be responsible for R and D.

Many speakers seemed to agree that although AECL had shown competence in R and D it should not become the implementing agency.

General Submissions

While the week was intended to deal with the three topics reviewed above there were various other submissions. Activist groups repeated many of the comments of the first week. (By titling their submissions on different topics the same groups or individuals were able to make several submissions.)

Comment

Throughout these first two weeks the Panel generally maintained a non-committal approach. Even when the patience of Panel members must have been tested by rambling and irrelevant presentations they did not show it.

It would appear that the Panel will end up choosing between three basic options:

(1) recommend that the government take no further action, i.e., leave spent fuel in storage;

(2) recommend that the technical examination of the deep geologic concept continue while also examining other options;

(3) recommend that the government accept the concept and proceed with the next step, siting, while continuing to fund AECL's examination of certain unresolved technical issues.

If the Panel chooses option (3) it will likely make strong recommendations regarding the siting process.

The other contentious issue is the structure of the implementing organization. Although the topic was not addressed until the tenth day it was clear that there are divergent views.

Postscript

The Phase I hearing wrapped up with two days in the town of Chalk River on May 2 and 3. Originally just one day was scheduled but the Panel added a half day to accommodate the number of applicants.

The focus of this session was on siting and the Panel received some sound advice and experience from those involved with the process that ended up with Deep River offering a site for low-level radioactive waste. Deep River Mayor John Murphy and Councillor Denise Walker provided the viewpoint of the municipality while Donna Oates and Dave Thompson, consultants, reviewed some of the pros and cons of the process followed.

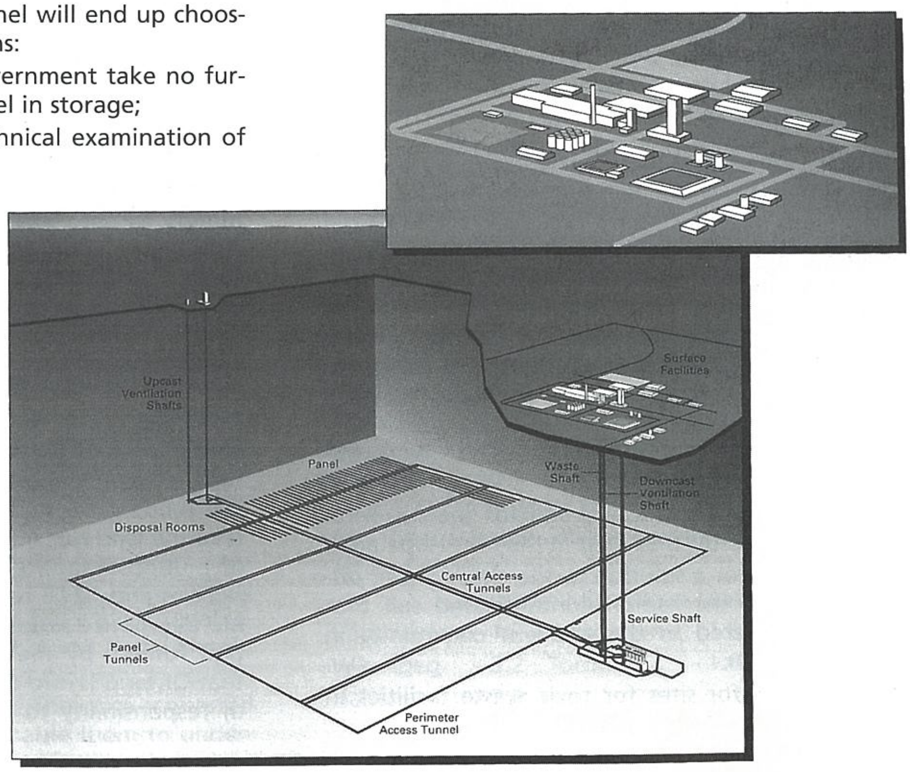
Supportive arguments for the concept by Archie Robertson, formerly of AECL - CRL, were over shadowed by his caustic criticism of the Panel and the hearing process.

Gordon Edwards got in another "kick at the can" thanks to the Panel's decision to split the Phase I hearings into several topical sessions.

Panel Chairman Blair Seaborn announced that he had received a letter from Dr. William Fyfe asking to resign from the Panel.

The Panel members now go away to try to digest the hundreds of thousands of words they have heard over the three weeks of Phase I hearings while preparing for the Phase II hearings on technical issues.

Artist's depiction of disposal facility (from AECL's "Environmental Impact Statement on the Concept for Disposal of Canada's Nuclear Fuel Waste.")



CNS Submission to the Nuclear Fuel Waste Management and Disposal Concept Environmental Assessment Panel

Ed. Note: *Following is the "executive summary" of the submission from the Canadian Nuclear Society to the Panel reviewing AECL's concept for deep geologic disposal of spent CANDU fuel. The full submission was presented orally on March 11, the first day of Phase I of the current set of Panel hearings, by Ken Smith, CNS Treasurer, who was also the principle author. The "Introduction", which provides the obligatory description of the Society and identifies the principle author, is omitted.*

Objectives of this submission

This submission has three general objectives:

- to present the opinion of CNS members that there is an ongoing need for safe, reliable, and cost effective nuclear power in Canada, and that an early decision on the concept for disposal of high-level radioactive waste will facilitate the continuing development of nuclear power to supply this need;
- to present the CNS opinion that the geological disposal concept that has been put forward by AECL is a viable, safe, and technologically sound method of disposal, and that the cost of deep disposal is small in comparison with the overall cost of electricity.
- to present the CNS opinion that concerns (expressed by various anti-nuclear groups) regarding the level of risk associated with deep disposal are unjustified. In fact, a strong argument can be made that predicted risks are so small that any further development effort should be directed at reducing the cost of the proposed facility, even if that resulted in a slight increase in the estimated risk of the concept.

Highlights of submission

The following points summarize the key conclusions and recommendations of the CNS submission:

1. If the consumption of hydrocarbon fuels and the release of "greenhouse" gases are to be maintained at acceptable levels in Ontario, the CNS believes that it will be necessary to maintain, and probably expand, the use of nuclear generation. Other environmentally acceptable means of base-load generation will not be able to meet all of Ontario's expanding electricity requirements.
2. The CNS believes that the used fuel disposal facility should have a minimum capacity of 5 million fuel bundles, and be capable of expansion to a capacity of at least 10 million fuel bundles. The design concept put forward by AECL has the capability to be sized to suit a wide range of capacity requirements.
3. The CNS believes that at least one concept for ultimate disposal of used fuel should be established, without delay. This would not foreclose the development of other concepts, nor does it mean that all of the used fuel generated over the long term must be disposed of according to this concept. The CNS believes that a delay in concept acceptance is unlikely to result in significant improvements in the concept.
4. The CNS believes that the Canadian nuclear industry should continue to accept responsibility for managing and disposing of used fuel so as not to burden future generations.
5. AECL's disposal concept utilizes conventional mining practices, and proven technology for the transportation of used fuel and containment of used fuel in long-life disposal containers. If further development work is to be undertaken, it should be aimed at establishing the adequacy of lower-cost designs and materials.
6. The estimated cost of the disposal concept is large, but acceptable in the context of the cost of electricity. Funds are being set aside by the utilities to cover the estimated future cost of disposal. This funding allocation amounts to about 2% of the commercial price of electricity.
7. The Environmental Impact Statement includes estimates of potential radiation exposures to both the workers and the public. The CNS is satisfied that the methodology employed by AECL in preparing these estimates is reliable. In all cases, predicted radiation exposures are below the AECB's exposure limits. In the case of the defined "critical groups" of the general public, exposures are far below normal background radiation levels.
8. There is no direct scientific evidence to establish adverse health effects of low-level radiation. The regulatory authorities have therefore adopted the very conservative "linear, no-threshold" (LNT) model for estimating health effects. AECL has estimated that the radiation exposure to individuals in a "critical group" living at the boundary of the disposal facility, 100,000 years after closure, is 10-3 mSv per annum. Applying the LNT hypothesis, the individual risk of fatal cancer in that critical group is 5x10-8 per annum (one chance in 20 million), which is effectively zero. For shorter time frames, the exposure levels are even lower.
9. In the context of the major benefits provided by

the use of nuclear power, the CNS questions the appropriateness of examining in minute detail the possibility of a very small increase in hypothetical risk associated with anything related to nuclear power, while generally ignoring the major and clearly definable risks associated with many other societal pursuits.

10. The Panel's terms of reference, as set out by the Government, state that "the energy policies of Canada and the provinces" and "the role of nuclear energy within these policies .... are issues that are outside the Panel's mandate". The Panel has been asked to examine the safety and acceptability of the proposed disposal concept, as well as "the social, economic, and environmental implications" of the concept. The question could be phrased in another way:

 "Given that funds are being collected by the utilities for the eventual disposal of used nuclear fuel, is the disposal concept put forward by AECL acceptable in terms of its social, economic, and environmental implications, including issues of public safety?"

The CNS believes that the answer is a strong YES.

SUMMARY

The CNS believes that AECL's disposal concept is technically sound, economically affordable, environmentally acceptable, and safe in terms of health effects. Furthermore, any postulated adverse health effects are very much smaller than those experienced in many other aspects of life, and in fact might be nil.

The CNS believes that the Panel should avoid any recommendation that requires more money to be expended in concept evaluation. It would be inappropriate to attempt to fine-tune our knowledge of a concept that poses negligible risk to society. Any further R&D expenditures would best be directed towards the reduction of the overall cost of the disposal concept, or to the examination of specific details related to potential disposal sites.

The CNS urges the Panel to find that AECL's disposal concept is acceptable, and recommend to the Government of Canada that it proceed as expeditiously as possible to begin the siting process.

The Panel in action. Blair Seaborn (centre) chairman of the Environmental Assessment Panel for the Nuclear Fuel Waste Disposal Concept addresses the audience in Chalk River, 2 May 1996, while his fellow members prepare for the presentations. L-R: Dr. Louis Lapierre, Pieter Van Vliet, Louise Roy, Seaborn, Dr. Lois Wilson, Dr. Denis Brown (off camera, Mary Jamieson)

Nuclear Waste Hearings – A Three Ring Circus?

by Hans Tammemagi

Ed. Note: *The following is a personal commentary by Dr. Hans Tammemagi on the hearings held this spring on the deep geologic concept for nuclear fuel waste disposal. Hans now runs his own consulting company, Oakhill Environmental, in St. Catharines, Ontario. Formerly he was with Acres International as manager of their Waste management division. Earlier he worked at AECL Whiteshell as head of the Geotechnical Research Section.*

An earlier contribution to the CNS Bulletin was his interesting article "A Waste Crisis - Two Perspectives" in Vol. 15, No. 2, summer 1994.

Hans produced the following article for the general print media. It was run, slightly edited, in the Ottawa Citizen and somewhat more abbreviated in the Toronto Star. While questioning the hearing process, his argument for approving the deep geological disposal concept is one of the few positive articles to appear in the daily press.

"Step right up, ladies and gentlemen," shouts the circus barker. "The show is about to begin". After seven years, the environmental assessment review of the safety of disposing of nuclear wastes by burying them deep underground has finally entered the public hearings stage. The final act has moved into the full glare of the public spotlight.

There is a lot at stake. Atomic Energy of Canada Limited (AECL), the proponent, has spent 20 years and $500 million studying methods to dispose of nuclear wastes. Disposal is a critical issue to the nuclear industry, which needs to demonstrate that the nuclear cycle can be safely "closed". Fearing that these hearings could be their Waterloo, the nuclear industry has mounted a do-not-spare-the-ammunition defense. With nuclear reactors accounting for 60% of Ontario's electrical supply, hundreds of billions of dollars are at risk, not to mention the energy security of the province.

On the other hand, nuclear opponents see the waste-disposal issue as the achilles heel of the nuclear industry, and they view this exposed flesh with the determination of a pit bull. They are at the hearings not only to criticize the disposal concept - but to topple the entire nuclear structure.

Sitting in the North York auditorium as the hearings opened, it was clear that this is no one-ring event, but the full three-ring extravaganza: television cameras and media people were everywhere; simultaneous translation in both official languages was available; printed copies of the presentations were stacked on sagging tables; court stenographers transcribed all presentations and questions.

The presentations began; the cameras rolled. Panel Chairperson Blair Seaborn, a thin regal-looking gentleman, rigidly enforced a 20-minute allotment for each speaker, followed by 10 minutes of question and answer. The panel of eight sits impassively, facing the audience like Buddhas. But as one listened to the presentations and the parade of questioners, a feeling of dissemblance invaded the room. Is this really a fair and objective way to make important environmental decisions - or is it an expensive sham? One almost expects a child to walk in, point at Mr. Seaborn, and ask "Mommy, why is he not wearing any clothes?"

Unlike other reviews conducted under the auspices of the Canadian Environmental Assessment Agency (previously the Federal Environmental Assessment Review Office), this one deals with a theoretical concept; there is no specific site. It's like assessing whether airports are a safe place to land airplanes without ever having built one. Such vagueness creates considerable confusion and many speakers wandered into other arenas. The future siting of a disposal facility or the more general question about the need for nuclear power were popular side excursions.

The issue is further clouded by the fuzziness of the proponent. Although Atomic Energy of Canada Limited has developed the deep-burial disposal concept and is defending it at these hearings, it is not clear who would actually site, construct and operate any future underground facility. Ontario Hydro appears to be the logical choice, as the creator and owner of 90% of Canada's nuclear waste, but is only playing a minor role at these hearings.

Distinct camps occupy two rings of this circus: the nuclear industry and the anti-nuclear (cottage) industry. This is a very polarized gathering - there is little middle ground.

The emotional character of the two antagonists offer a stark contrast. The nuclear industry is from Mars. They are nuclear technicians, many with Ph.D.s, and talk in a jargon of scientific terms. Their conversations are constructed with the precision of logic and buttressed with Sieverts and Becquerels and risks of ten to the minus six, and other strange terms that to most people have the familiarity and reassurance of Zwahili.

The anti-nuclear (cottage) industry is from Venus. Emotions rule on this planet. Their arguments are based on warm motherhood feelings, not on analyses. "The main problem with the disposal concept", stated the representative for one group, "is that AECL has not provided enough information to make a decision." She then proceeded to declare, oblivious to the contradiction, that her group was strongly opposed. This, "Don't bother me with the facts, I've already made up my mind", attitude prevails on Venus.

Ethics was the topic for this week - which sums it up in a nutshell. The two sides have defined their own ethics. It's the infidels against the Christians, fundamentalist Islamics against Orthodox Jews - neither group will accept the ethics of the other.

It is interesting to explore how these positions developed. The nuclear industry is part of our modern high-technology society and the things it craves: the televisions, the VCRs, the cars, the high-speed transit systems, mountain bikes. Most of these would not be possible without electrical energy. The nuclear industry is only responding to these societal demands. They are technicians providing a technical service.

To the anti-nuclear groups, and to a great segment of our population, the nuclear industry represents everything that is wrong with society: degradation of the environment, the loss of identity and the associated angst and the stress that has come with increasing technological complexity, burgeoning population, and urbanization. We all share this frustration.

Nuclear energy has become the fall guy, the convenient one-stop shop, for venting our frustrations and helplessness at this complex and stressful society.

The most exciting part of the show is that everyone can indulge in the fun game of nuclear bashing. "Step right up and try to dunk the nuclear representative. The balls are free and you get as many throws as you want." The nuclear technicians have the befuddled and hurt look of a dog who has brought his master his slippers, only to be met by a cuff across the ears. In spite of responding to the public's need for safe disposal of nuclear waste - and by all accounts the proposed concept is far superior to the technologies currently used to dispose of highly-hazardous non-radioactive wastes - AECL has been accused of withholding information, of being immoral, evasive, dishonest, and much more.

Even the federal government, who introduced nuclear power to this country in 1945 and has supported it ever since, is lining up to take a kick at AECL. Environment Canada, the nation's environmental watch dog, has undertaken a massive study of the concept. Their report finds fifteen major and thirteen minor deficiencies in AECL's proposal.

A cynic might construe that the purpose of the review process is not to protect the environment, but rather is a clever delaying tactic by politicians who wanted to avoid the heat associated with this emotional topic. As such, it has worked amazingly well. The hearing process started in 1989 and is now in its seventh year - and there is at least one more year to go before any recommendations are handed down. Two panel members have already passed away.

The hearing process is a mini-industry all by itself. There are eight panellists, a scientific review group of 14 eminent scientists, and two administrative staff. They are all on the pay roll - no volunteer work here. In addition there is a professional facilitation group which arranges the public meetings, translators, court stenographers, and a whole team of others who toil to ensure the show goes on. Approximately $700,000 has been given to intervenor groups to do their own studies of AECL's environmental impact statement and to make presentations to the panel. The total cost of hearings alone, i.e. only the process, not the research by AECL, nor the studies by Environment Canada, will run around $10 million by the time all is said and done.

In the final analysis, what will these hearings prove? In fact, not much. The outcome has been apparent since the outset.

In spite of the impassioned criticism of deep burial, no one has offered a better solution, nor have any serious technical flaws been unearthed. Besides, what alternatives do we have? Canada already has a large stockpile of used fuel, and more is being amassed every day. During the course of these hearings, about 13,200 tonnes of additional highly radioactive waste will have been created. This spent fuel isn't going to go away by itself.

It's unfortunate that the nuclear industry has become the public symbol for the many ailments of society. But, in the final analysis, that is what it is, only a symbol. We all still want and need the comforts provided by it. However, it's a wonderful show, and P.T. Barnum would have been proud.

Canadian Nuclear Society 17th Annual Conference

Fredericton, New Brunswick 9 - 12 June 1996

The 17th Annual conference of the Canadian Nuclear Society will be held in Fredericton, New Brunswick, from the 9th to 12th of June 1996, in conjunction with the 36th Annual Conference of the Canadian Nuclear Association.

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Commissioning and Initial Operation

Pickering Dry Storage

by Steve Jonjev

Ed Note: *The following article is a slightly edited version of a paper presented at the CNS sponsored "First International Conference on CANDU Fuel Handling" held in Toronto, May 13, 14, 1996.*

1. INTRODUCTION

Implementation of the dry storage concept at Pickering Nuclear Division (PND) followed a successful demonstration program, which used two concrete containers loaded with six and ten years cooled irradiated fuel from the Auxiliary Irradicated Fuel Bay (AIFB) (1988-1992). Results of this program confirmed both the technical and economical viability of the dry storage system as an alternative to the conventional wet storage system. The current Dry Storage Container design offers two main features:

- interim dry storage of irradiated fuel for up to 50 years
- a means of transportation to its final disposal destination without the need to re-package irradiated fuel

The Used Fuel Dry Storage Facility (UFDSF) will provide additional on-site storage for about 576,000 irradiated fuel bundles using approximately 1,500 DSCs by the end of station operating life (year 2025). The UFDSF currently has an operating license as well as a transportation license (for DSC off-site shipment) granted by the Atomic Energy Control Board (AECB).

International Atomic Energy Agency (IAEA) safeguards are applied to the facility and containers. Surveillance cameras are installed in the UFDSF workshop and storage area, and permanent safeguards seals are applied to each container by installing two fibre optic cables and attaching "cobra" seals.

2. COMMISSIONING

2.1 Pre-Loading Activities

New containers are delivered to the dry storage facility workshop where they are unloaded from a truck and temporarily stored. Prior to transferring the first empty DSC (#OH-0001) to the auxiliary fuel bay, it was inspected for corrosion and other physical damage. A lid and transfer clamp were installed to verify a proper fit. Four empty modules were placed into the container to verify proper clearance between in the cavity, and that the lid would not contact the uppermost module. Each container has two ports, a vent at the top and a drain at the bottom. The internal threads of these two ports were inspected for any damage and repaired as necessary. With the lid taken off the container body, the main weld groove was carefully inspected for rust. None was found. The prepared container was placed in the temporary laydown area, ready to be taken to the auxiliary fuel bay.

At the same time as the container inspection, two operators were recording serial numbers of the bundles in the bay to be loaded. This was done using a telescope and recording equipment specially fabricated for this task. The process was quite lengthy (it took about 3 days vs. the 4 hours expected), but, at the end, a complete record of the 366 bundle serial numbers was available. This requirement came from the AECB and IAEA in mid 1995 and was agreed upon by PND. Before the loading of the DSC, IAEA staff performed the following verifications:

100% item count, (i.e. 366 bundles)

Non Destructive Analysis (NDA) of irradiated fuel

correctness of serial numbers by checking 8 out of 366 bundles

This task was very cumbersome, and took about 12 working hours vs. the 2 hours originally planned.

2.2 Loading of Container in Auxiliary Fuel Bay

The fully prepared container was transported from the facility workshop to the auxiliary fuel bay along the route north of the powerhouse by the on-site transporter vehicle (Fig.#2). In the auxiliary fuel bay, the lid was taken off and the container was filled with demineralized water. On November 29, 1995 it was submersed into the auxiliary fuel bay, placed on an impact pad, and loaded with four modules of approximately 17 years cooled irradiated fuel; a total of 366 bundles. This operation was performed under surveillance of the IAEA and AECB staff and various station personnel. Once the lid and in-bay clamp were positioned and engaged on the container, it was hoisted out of the water. Total in-water time was 1 hour, 43 minutes, which is considerably less than the originally estimated 3 to 4 hours. Radiation fields on the container after loading were measured as 0.5 mrem/hr at contact and non-detectable at working distance. It should be noted that radiation fields at contact rose marginally after draining as the shielding from the water was lost.

The container was then immediately washed in the decontamination pit for about 15 minutes with water heated to about 75oC. After placing the container back on the handling pad, it was allowed to dry before taking smears from the surface. The smears showed zero surface contamination, which was much

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better than expected. It reflects the positive aspects of maintaining clean bay water, minimizing in-water time and ensuring a prompt washing with hot water after removal from the bay water.

2.3 Draining and Vacuum Drying

On November 30, 1995 the water in the container was drained back into the auxiliary fuel bay by gravity, with both drain and vent ports open. It took 15 minutes to reach the point where no water was flowing through the drain port. The drain port was then closed, and the transfer clamp was installed on the container flange.

This method of draining, although it had worked well during "dry" commissioning, left about 55 litres of water in the container cavity versus the expected 10 litres. The draining of the water from subsequent containers was vastly improved by tilting the container in two different directions. It is believed that most of the water was trapped amongst the fuel bundles in the module tubes.

The vacuum drying system was connected and allowed to run for 14 hours. Water was continuously removed, and internal pressure was lowered from atmospheric to 13 mbar(a). Although the target of 2.5 mbar(a) was not achieved, and the container had obviously not been completely dried, it was decided to transport it to the facility and resume vacuum drying there.

2.4 Transport

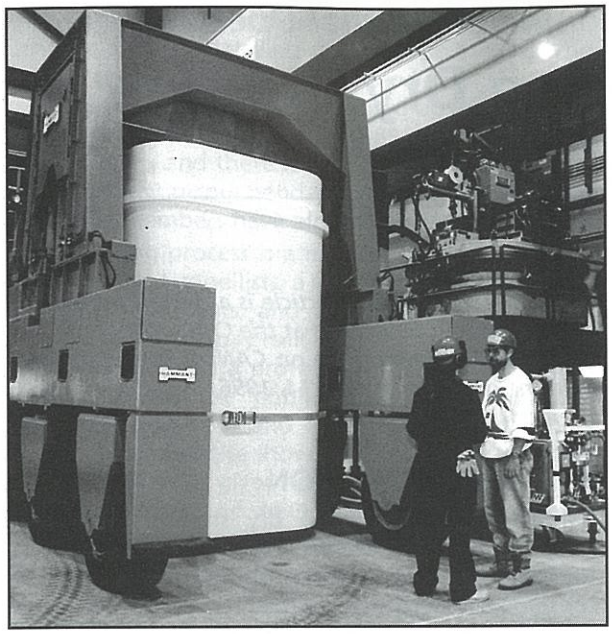
Final contamination surveys found only one area on the base of the container with 1000 cpm of loose contamination which was easily removed. This is a sign that the sweating phenomenon that had been observed during the demonstration program is not taking place. Gamma surveys found fields still at about 0.5 mrem/hr at contact and zero at working distance.

By means of a special "O" ring seal placed in the welding groove, a sub-atmospheric pressure of less than 830 mbar(a) was established in the container cavity. This sub-atmospheric pressure was maintained during the transport through the station yard to prevent the possible spread of loose contamination.

On December 1, 1995, having been picked up by the Transporter vehicle (fig.#3), the container was taken to the facility workshop. Along with station and AECB personnel, IAEA staff accompanied the container as part of "human surveillance" on its 18 minute trip to the auxiliary fuel bay. The Transporter worked flawlessly throughout this process. At the UFDSF, the DSC was first dropped off by the Transporter, then moved by crane to welding station #3. IAEA staff then applied a security seal to the base, which was an additional safety measure to being monitored by the permanent surveillance cameras. The container internal pressure rose only marginally during the trip.

2.5 Vacuum Drying

Upon arrival in the auxiliary fuel bay, about 20 litres of water was collected through the drain port.



Rearview of Dry Storage Transportater. The welding machine and mock-up are in the background.

It is believed that this water was forced out from the module tubes by vibrations during the trip through the yard. This was followed by two days of vacuum drying in an effort to completely dry the container internals. However, internal pressure only got down to 7 mbar(a) and the presence of water was still evident. In an attempt to attain the required dry condition that had been observed during the testing stage, vacuum drying of the container proceeded non-stop for two more days. On December 5, 1995 an internal pressure of 5.5 mbar(a) was achieved with no further water being removed. This was deemed to be an acceptable condition for the initial stage of drying prior to welding the lid to the container body.

2.6 Welding and X-ray

The flange weld, about 30 feet long, is made by two automatic welding heads, each traveling along the circumference of the lid on opposite sides (fig.#3). Prior to welding, the container flange must be preheated to 105°C, while a slight vacuum is drawn to prevent any spread of contaminants. During earlier tests, it was confirmed that a pre-heat period of 16 hours is required to literally "soak" the container lid and body with heat so it will not cool down before the first welding pass is done. The design estimate had been 8 hours.

Preparation of the container for welding of the flange took several days, and some of the work was done in parallel with vacuum drying. First, primer paint had to be ground off the weld groove down to bare metal. Then, the welding machine was installed and put through a series of checks. A problem with one of the trailing cameras was discovered and quickly rectified. By December 7, 1995 the preheaters and thermo-couples were installed and function tested.

Having sufficiently pre-heated the container flange,

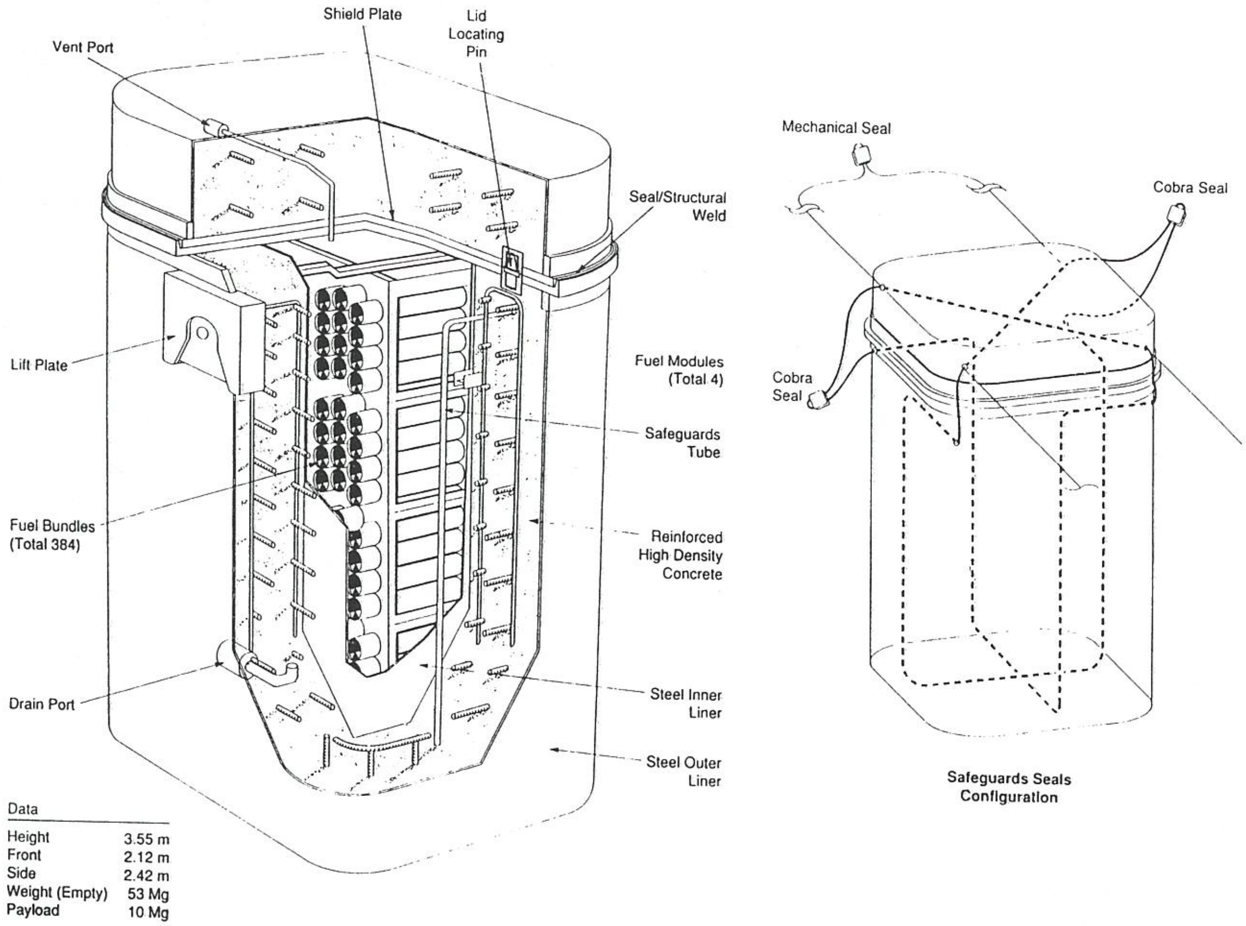


Figure 1
Dry Storage Container for Used Fuel Storage

the pre-weld vacuum system was disconnected and the first weld pass completed on December 12, 1995. Constant monitoring of the process from the control room, as well as frequent local visual inspection by the welders, was required to ensure a flawless weld. It took about two days to complete eleven passes, seven of which were done on the first day.

The welding machine was removed from the container, the X-ray machine installed and the weld allowed to cool down for 48 hours. In the meantime, the container internals were maintained slightly sub-atmospheric by connecting the drain port to the active ventilation system. The flange weld was inspected using the X-ray machine (radiography). To reduce the X-ray hazard, it was performed in the evening hours, and was completed on December 16, 1995. There were no flaws found and the weld was deemed acceptable.

2.7 Helium Backfill and Leak Test

During the final vacuum drying, which took less than 2 hours, a pressure of 1 mbar(a) was reached, indicating that practically no water remained inside the DSC cavity. It was subsequently backfilled with helium to about 930 mbar(a).

Manual welding of the vent and drain ports took substantially more time than expected. However, the welds were all found to be good and did not require any re-work. Each weld required 8 hours vs. the 2 hours originally estimated.

The helium leak test requires repositioning the DSC to station #4, which has the necessary equipment and instruments for this test (fig.#4). The unique test method uses a two piece "bell-jar" so that the whole container can be tested at once. A vacuum is drawn in the space between the container outer surface and the bell-jar so that any leakage detected. Having placed the container into the bell-jar, it took 26 hours to pull the required vacuum of 15-20 micro-bar(a). This lengthy process was expected, mainly due to out-gassing of outer surface with its coating of epoxy paint. The helium leak test was performed within the next five minutes, and it showed zero leakage (acceptable leak rate is 1x10-5 cc/sec). For all practical purposes, the container was ready to be put into final storage on December 21, 1995.

Having painted the welded surfaces, and having installed the safeguards "cobra" seals, the actual placing of the container in the storage area and a ribbon cutting ceremony took place on January 23, 1996.

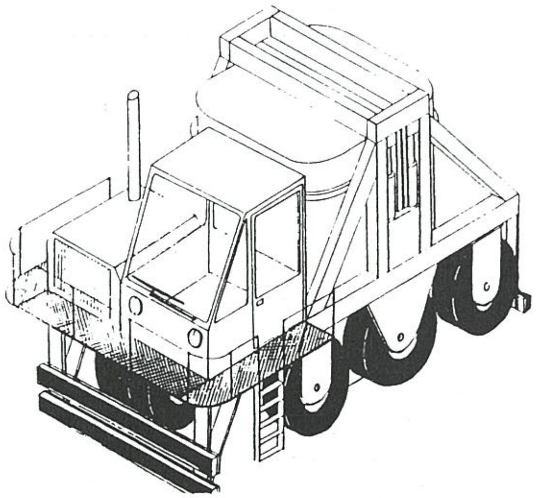


Figure 2
On-Site Transport Vehicle

2.8 DSC History Records

Detailed information will be computerized, with hard copies kept in the station's Q.A. vault. Included will be each containers serial number with manufacturing data, the modules' serial numbers, the age of the irradiated fuel, the position of modules within a container, the number of bundles in each module, date of loading, as well as X-ray and helium leak test results. This has all been recorded in a checklist and verified by station and IAEA staff. The facility storage area has a simple grid system and each DSC has a nameplate.

All information listed above is currently kept in the form of a "DSC history docket".

3. RESOURCE REQUIREMENTS

About 314 personhours were required to complete the first transfer, from start to finish. Contrary to original estimates, mechanics were in the highest demand, followed by operators and quality control staff (see Table 1).

Once the whole process becomes routine, it is expected to take about 160 personhours per container.

4. OCCUPATIONAL RADIATION SAFETY

4.1 Station Personnel

The shielding provided by the container proved to be much better than anticipated, and resulted in gamma fields of less than 0.6 mrem/hr at contact with the surface and zero at 1 metre distance. Also, by keeping the bay water very clean, the gamma background fields in the auxiliary fuel bay are very low (about 0.25 mrem/hr). As a combination of these two factors, the gamma dose received by operators totalled 10 mrem per DSC (5 operators were involved). Similarly, the total gamma dose received by mechanical maintainers was about 10 mrem. Other work groups received no measurable gamma dose. There was no Tritium dose received while working in the auxiliary fuel bay.

Therefore, the total radiation dose received by all work groups was about 20 mrem per container, which compares favourably with the original estimate of about 75 mrem per container.

4.2 General Public

Radiation fields at the outside surface of the storage building wall were about 33 micro-rem/hr, which is far below the target of 250 micro-rem/hr. These radiation fields may marginally rise as the number of containers in the storage building increases. However, the actual dose rates to the general public at the exclusion zone boundary will be well below the design target of 1% of the regulatory limit.

Air emissions to the environment from the facility workshop (zone 3 from the radiation point of view) are monitored and were found to be zero. There has been no active liquid discharge from the facility workshop thus far.

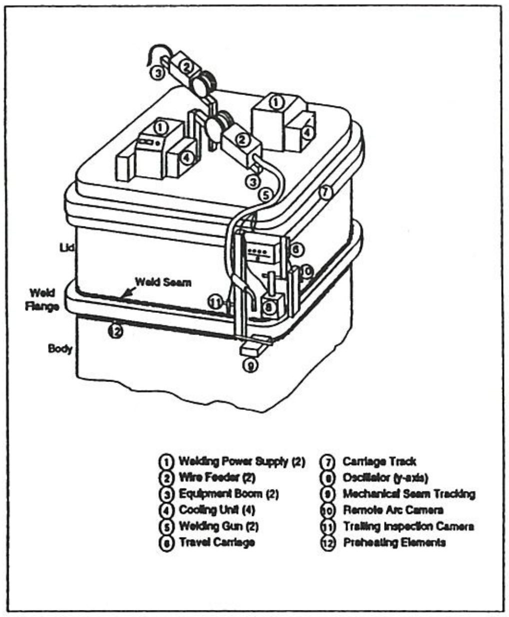
5. INITIAL OPERATION

The initial production runs took place from the "B" Irradiated Fuel Bay (IFB-B) because of the proximity of its fill-in date. They yielded a transfer capability of four (4) containers per two months. Full production transfer capability of eleven (11) containers every two months will be required by early 1997, just before the auxiliary fuel bay becomes full. A total of sixty-six (66) containers will have to be transferred from then on every year, assuming the eight Pickering reactors are operating at an average 85% Capacity Factor.

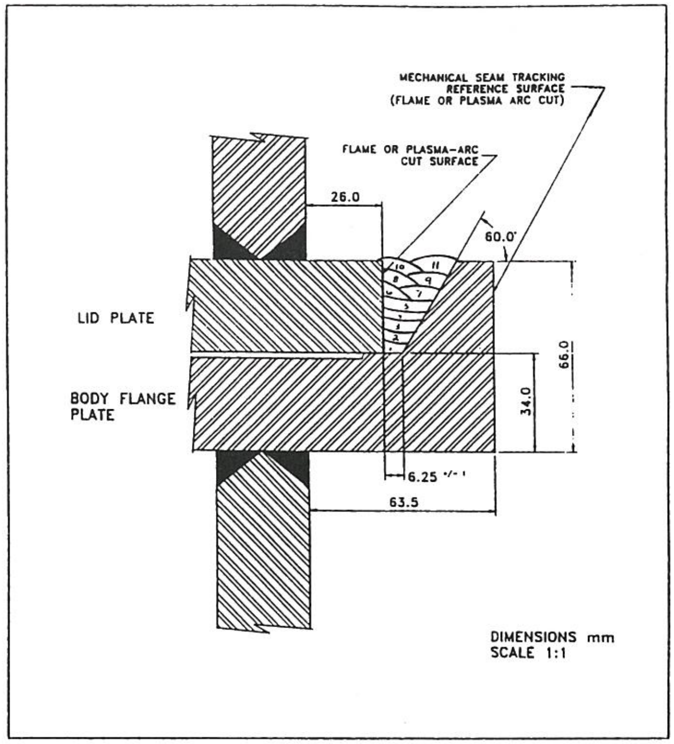
Major difficulties encountered thus far are listed below:

- Draining of water from the container was inadequate causing very long vacuum drying periods. This has been overcome by tilting the container in two different directions. However, the Lifting Beam suffered minor damage since it had not been designed for tilting. A design change is expected to take place shortly.
- Welding of the vent and drain ports took two days. It will be reduced by using modified procedures.
- Welding of the lid to the container body (flange weld) was not satisfactory on the first three containers. Extensive re-work has been required due to porosity and lack of fusion, predominantly in the root of the weld (the first of eleven passes). An investigation is in progress while the welding of the flanges carries on at a slow and resource-consuming pace.
- The helium leak test on its own does not take more than 5 minutes. However, it requires a vacuum in the bell-jar of 15 - 20 micro-bar(a), which needs in

UFDSF DSC LID TO BODY REMOTE WELDING



LID REMOTE WELD ILLUSTRATION



DSC LID-TO-BODY WELD JOINT

Figure 3
DSC Lid to Body Remote Welding

UFDSF DSC HELIUM LEAK DETECTION (BELL JAR)

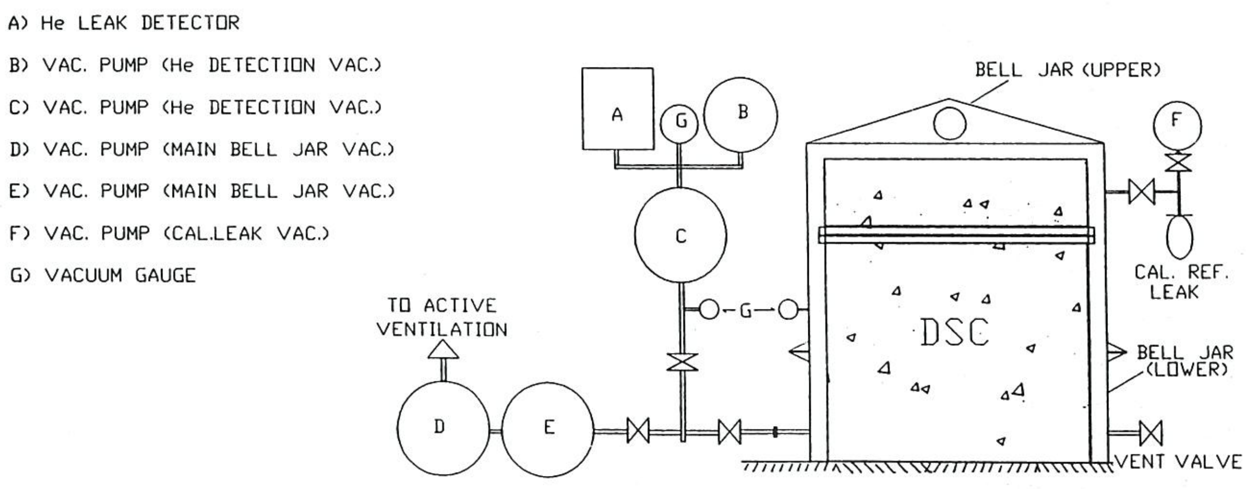


Figure 4
DSC Helium Leak Detection

excess of 24 hours to achieve. It is believed that recalibration of the leak detector to operate at a vacuum of 1 mbar(a) will reduce the total test time to less than 4 hours.

- A lack of manoeuvring space in the "B" fuel bay area is slowing down the process. Particularly, the rationale for the portable impact pad is being questioned in view of limited container movements. Also, the manoeuvring sequence of equipment such as the in-bay clamp stand and lifting beam stand will have to be improved upon.

All of the above, plus other minor factors, contribute to the current transfer rate being about 15 calendar days per container. This transfer rate must be improved to about 5 calendar days per container by early 1997 in order to maintain the power level of the eight Pickering reactors at an average 85% Capacity Factor.

ACKNOWLEDGMENTS

The author wishes to thank Ms. C. Walker and Mr. D. Hunter for their help in preparing this paper.

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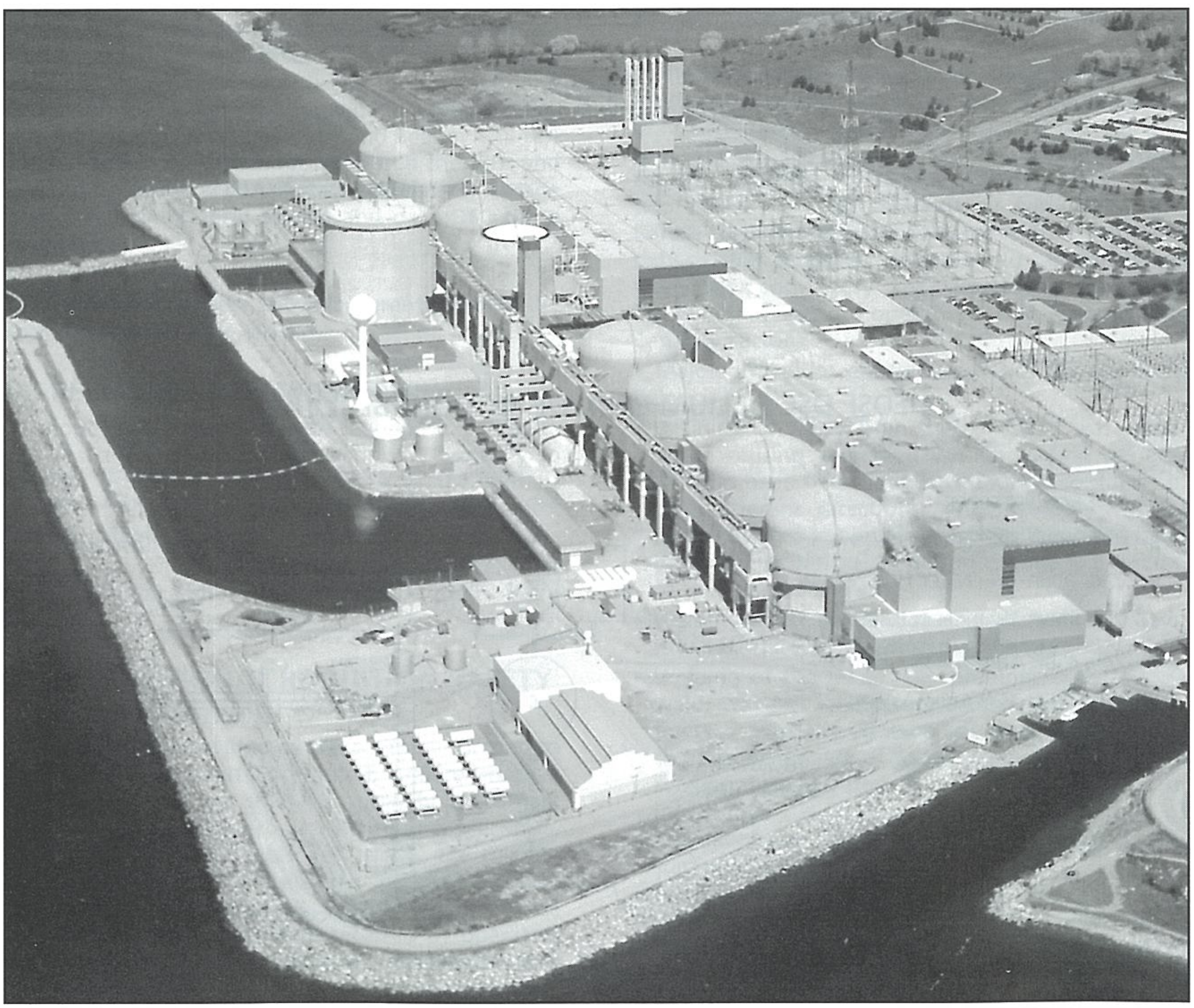
An aerial view of Pickering NGS showing the Dry Storage Module yard and facility in the foreground.



Assessment of the Cosmic Radiation Field at Jet Altitudes [1]

Pamela Tume [2]

ABSTRACT

A two-phase investigation was undertaken to measure the high-altitude radiation field and to survey military pilots to determine their annual total dose equivalent. From the measurement phase in which two dedicated flights were undertaken, the ionizing dose rate in air ranged from 1.6 to 3.1 μGy/h + 15% (from 33,000 to 41,000 ft and from 52 to 70°N geomagnetic latitude). The neutron dose equivalent rates were 6 to 4.5 μSv/h ± 50% (in ICRP-60) for the northern (~37,000 ft) and southern (~35,000 ft) routes, respectively. Neutron-sensitive bubble detector measurements indicated that the neutron component is distributed uniformly within the aircraft (± 30%). From the survey phase, the annual occupational total dose equivalent of military pilots was found to be below the current limit for the public and may exceed the ICRP-60 recommended limit.

I. INTRODUCTION

Aircrew are normally considered to fall within the radiation exposure guidelines for the general population. However, current international consensus suggests that aircrew at jet altitudes should be classified as occupationally exposed personnel in accordance with ICRP-60 recommendations[1]. Earlier studies have indicated that commercial aircrew will exceed the ICRP-60 recommended limit for the general public of 1 mSv/y, (which is five times lower than the current limit)[2, 3, 4].

The high-altitude radiation environment in an aircraft is due to the interaction of energetic galactic and solar particles with the Earth's atmosphere[4]. The resulting radiation field consists of both low (i.e., gamma-ray, fast charged-particles) and high (i.e., mostly neutron) linear energy transfer (LET) radiation. Overall, the radiation field intensity has been shown to increase with both altitude and geomagnetic latitude, with some uncertainty in the particle energy spectra. This is especially the case for neutrons which account for ~50% of the total dose equivalent received during high-altitude flights[4, 5, 6].

As such, the authors have undertaken an investigation of this radiation field in the form of a two phase study that was sponsored by Canadian Forces (CF) Air Command. The measurement phase, which consisted of dedicated scientific flights, provided a means to characterize the ionizing and neutron radiation fields from 52° to 70°N geomagnetic latitude and at five altitudes from 33,000 to 41,000 ft. The results are therefore representative of the harsher radiation environment found on northen commercial air routes. In the survey phase of the study, a group of CF pilots carried bubble detectors (BDs) during their routine duties for a period of one year. From bubble and altitude history data, and using the dosimetric and spectral information obtained in the measurement phase, the total dose equivalent of each route was estimated. The annual total dose equivalent was also calculated using pilot flight profile information.

II. MEASUREMENT EQUIPMENT AND METHODS

A. Gamma Spectroscopy and Low-LET Dosimetry

Gamma radiation inside jet aircraft results from: (i) direct production by cosmic-rays, (ii) production by secondary radiation reactions with the aircraft structure, and (iii) high-energy Bremsstrahlung radiation from charged-particle interactions. These different sources can be separated by an examination of the spectral results.

Two of the gamma spectrometer systems employed during this flight were a 2"x 2" Crystal BGO scintillation counter without an anticoincidence shield, and a 2"x 2" Crystal NaI(Tl) DOSPECTm system (which is a hand-held automated unit modified to extend its response to 8 MeV). Both a pressurized ionization chamber (IC) and thermoluminescent detectors (TLDs) were used to measure the low LET dose from gamma-rays and charged particles (e.g., electrons, muons, fast protons). The IC is calibrated using a National Institute of Science and Technology radium source and adjusted for cosmic rays[7]. The TLDs chosen for the flights were Al_2O_3, ^7LiF:Mg,Cu,P (LiF) and CaF_2:Mn. The first two types of TLDs are especially useful as low level gamma-ray dosimeters for mixed radiation fields.

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1) Winning paper, Doctorial category, 1996 CNA/CNS Student Conference. 2) Department of Chemistry & Chemical Engineering, Royal Military College. 3) Supervisors: Dr. B.J. Lewis, Dr. L.G.I. Bennett, RMC; Dr. T. Cousins, Defence Research Establishment, Ottawa

B. Neutron Spectrometry and Dosimetry

Since the shape of the neutron spectrum and its contribution to the total dose equivalent are not confirmed, a modified portable multisphere neutron spectrometer system (MNS), lead-covered (LCRM) and conventional rem-meters, and BDs were flown (see Table A). The BDs were also used for the survey phase of the study (see section III).

1. Neutron Spectrometry. The MNS consisted of spherical polyethylene moderators of different sizes surrounding thirteen high pressure (4 atm) ^{3}He proportional counters which detect slowed-down neutrons. In addition, a 25-kg lead shell was placed within one 30-cm diameter polyethylene sphere to boost the response to high-energy neutrons by capitalizing on Pb(n,2n) and Pb(n,3n) reactions[8]. All detectors of the MNS were operated simultaneously, permitting complete spectral measurements at five minute intervals in the low intensity field at altitude. At present, the response matrix of this system is being modelled.

2. Neutron Dosimetry. For most terrestrial applications, fast neutron detection equipment can be calibrated with radioisotopic sources (e.g., AmBe, PuBe) for applications in areas with fast neutrons below 20 MeV. Unfortunately, the cosmic-ray neutron spectrum extends to hundreds of MeV, as can be seen in the data of Hess et al.[9] (Fig. 1). Consequently, the response of the neutron dosimeters (Table B) was characterized by a simulated normalised cosmogenic field at the TRI University Meson Facility (TRIUMF). The TRIUMF spectrum shares the evaporation peak at 1 MeV as seen in the Hess results. However, the TRIUMF spectrum has an additional feature near 100 MeV. Although it has been argued that this feature should also exist in the Hess spectrum, it has not been clearly observed in cosmic-ray neutron measurements[4].

In order to determine the importance of the spectral shape to the neutron dose equivalent, the response of the detectors to PuBe and TRIUMF neutron spectra were examined. As shown in **Table** B, the response of the LCRM to the neutron field at TRIUMF

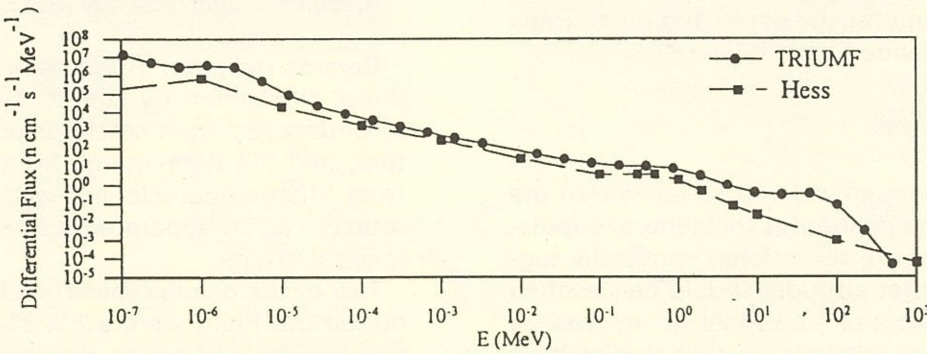

Fig. 1. Hess and TRIUMF neutron spectra.

Table A. Neutron Dosimeters used in the Present Study

Detection System	Remark
Plain Rem-meter	9" wax sphere which surrounds a BF_3 detector
Lead-Covered Rem-meter (LCRM)	Modified plain sphere to include a 0.5" lead shell on the outside.[a]
Temperature Compensated Bubble Detectors (BD-PND, or BD)	Nominal sensitivity of 6.0 bubbles/μSv (over 20 to 40°C for an AmBe neutron spectrum and NCRP-38 recommendation).

[a]response determined to 400 MeV using ANISN and the HIL086 cross section set; modelled using a PC version of LAHET.

Table B. Measured Neutron Dosimeter Responses to PuBe and TRIUMF Spectra

Spectrum	LCRM (counts/h)	Plain (counts/h)	BD[c] (bubbles/h)
PuBe[a]	7862 ± 89[a]	7059 ± 84 [a]	240 ± 48 <20 to 40°C>
TRIUMF[b]	9390 ± 330[b]	4983 ± 135[b]	414 ± 95 <26 to 28°C>[d]

[a]54 μSv/h ICRP-60; [b]84 μSv/h ICRP-60; [c]For a 6.0 bubble/μSv detector; [d]Interpolated (see text).

is double that of the plain rem-meter, whereas the response to the PuBe spectrum was basically the same for the two detectors.

Because of concerns that the response of the BDs could be affected by changes in cabin air pressure and temperature, as well as the neutron spectrum, both the temperature-pressure and the temperature-energy response of BDs to different spectra were investigated. For the pressure investigation, it appears that up to 10,000 ft equivalent altitude (and between 20 to 32°C), the BD response is within the expected uncertainty of ±30%. This means that depressurization would not significantly affect the BD response. During the flight, the BDs were maintained at a constant temperature of 22°C by surrounding them with 5 cm of styrofoam insulation, and using a resistive heating unit.

The effect of temperature on the energy response curve has not been measured for this BD model. Temperature-energy response curves do, however, exist for a similar model, the BDS-100 which has the same 100 keV threshold as the present detector[10]. As such, the BD was assumed to have the same temperature and energy response function as the BDS-100. Using this energy response function, a calibration factor can be developed to predict the dose equivalent for a given neutron spectrum and temperature[2]. For the TRIUMF spectrum, the calibration factor is calculated to be 4.8 bubbles/μSv (or b/μSv) ± 10% in ICRP-60 ambient dose equivalent units[11, 12] averaged over 26 to 28°C. This compares favourably with the actual measured response at TRIUMF (i.e., 4.9 b/μSv ± 23% at 26 to 28°C and for ICRP-60 units). For the in-flight measurements carried out at the lower temperature of 22°C, the calculated calibration factors for the Hess and TRIUMF spectra are 3.9 b/μSv ± 10%, and 3.3 b/μSv ± 10%, respectively. The small difference between these numbers (15%) result from the slight difference in the energy spectrum, i.e., the 100 MeV peak.

3. Anthropomorphic Phantom. A Humanoid RT-200 Anthropomorphic Phantom, consisting of an average male skeleton encased in a tissue-equivalent plastic to resemble a human form, was utilized to determine the dose distribution in the human body. It has a sliced and gridded structure which allowed internal and external placement of TLDs and BDs.

C. Flight Path

Details of the high-altitude flight path are shown in Fig. 2 for the round trip flight (Trenton, Ontario, Canada to Köln, Germany) from May 9-11, 1995. The flight path was deliberately chosen to maintain a specific geomagnetic latitude, more northern on the outbound flight and more southern on the return flight.

III. RESULTS

A. Measurement Phase

1. Gamma Spectrum. There were two peaks discernible in the spectrum from the 2" x 2" BGO spectrometer. The first observed photopeak was the 511 keV positron annihilation peak. The second peak at 2.2 MeV may be associated with thermal neutron capture in hydrogen, probably in the fuel. The main spectral difference from a ground level (i.e., terrestrial) gamma ray spectrum was the high energy contribution above a few MeV. The dose rate, as measured with the DOSPEC, decreased soon after takeoff due to a decrease in the intensity of the natural radiation from the Earth as the detector moves farther away. The radiation intensity subsequently increases with

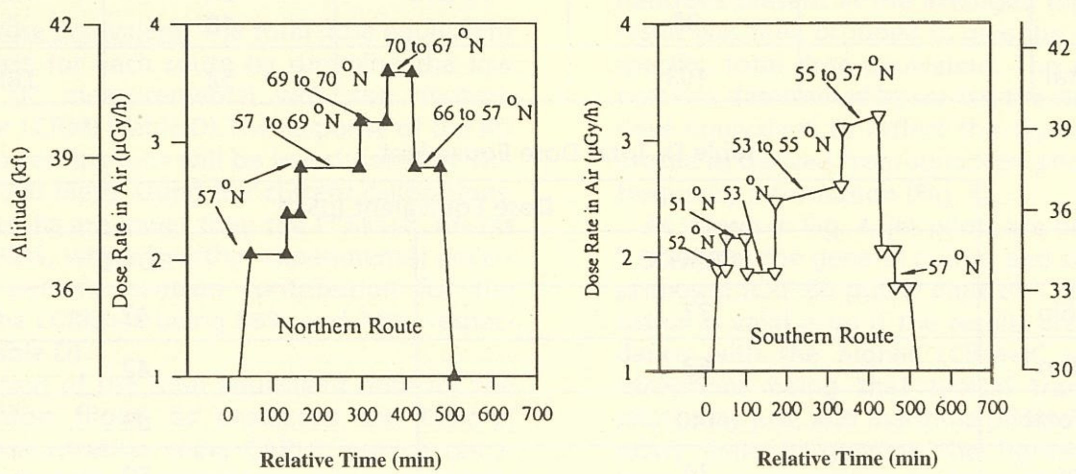

Fig. 2. Ion Chamber results for May 9 and 11, 1995.

altitude as one enters the cosmic radiation field in the atmosphere.

2. Low LET Dosimetry. From the IC data (Fig. 2), it is clear that the air ionization dose rate increases with altitude and varies slightly with geomagnetic latitude. For the northern-route (outbound flight), the dose rate was constant at constant altitude, whereas for the southern flight variations of up to 8% were seen with changes in latitude. The lack of change in dose rate for geomagnetic latitudes above 57°N geomagnetic is referred to as a latitude "knee" and has been observed by others[4]. Integrating over time, the IC tissue dose was found to be 19 ± 3 μGy and 17 ± 3 μGy on the northern and southern routes, respectively. [The conversion of 1 R air to 1 Gy in soft tissue relies upon the factor of 1 R per 0.96 rad, which is valid for X-rays and gamma rays to about 1 MeV[13],] In comparison, the low LET dose (for the round trip) measured by the Al_2O_3 and LiF TLDs were 34 ± 3 μGy and 42 ± 4 μGy, respectively which is in good agreement with the IC measurement (36 ± 5 μGy). The dose distribution inside the phantom was uniform to within experimental uncertainty and equal to the free field measurements.

3. Neutron Spectrum. Preliminary analysis of the raw detector counts indicates that the fluence below 20 MeV is increased by a factor of 1.6 between 33,000 and 41,000 ft. It appears that the spectral shape of this region did not change for these altitudes.

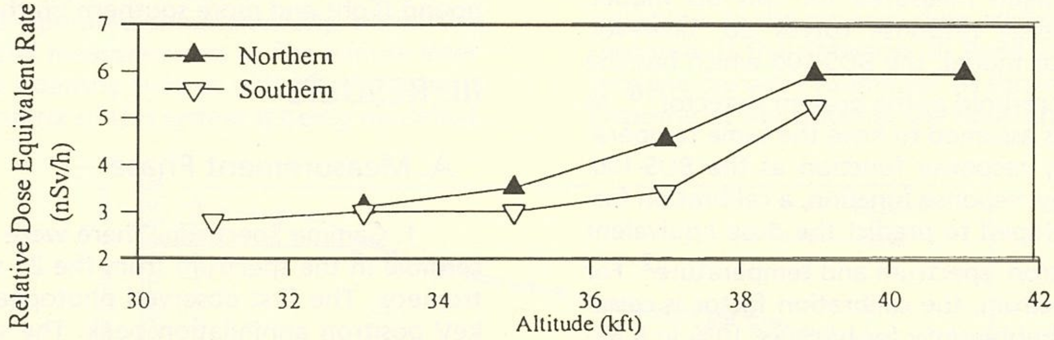

Fig. 3. Lead covered rem-meter relative dose rate with altitude.

Table C. Route -specific Rem-meter and Bubble Detector Neutron Dose Equivalents (DE) for Various Spectra

Route	LCRM		BD-PND		Calibration Field
	counts	DE (μSv)	counts	DE (μSv)	
Trenton - Köln	6463 ± 80	58 44	91 ± 24	28 20	TRIUMF PuBe
Köln - Trenton	5289 ± 73	45 36	79 ±12	24 18	TRIUMF PuBe
Round-Trip Total		103		52	TRIUMF

Table D. Total Dose Equivalent

	Dose Equivalent (μSv)[a]	
Route	LCRM+IC	BD+IC
Trenton - Köln	77	47
Köln - Trenton	63	42
Round-Trip Total	140	89
% neutrons	74	58

[a] TRIUMF calibration factors in ICRP-60 ambient dose equivalent units.

4. Neutron Dosimetry.

4.1. Rem-meter. The relative dose rate profile for the LCRM indicates that the count rate increases with altitude and geomagnetic latitude (Fig. 3). Furthermore, the LCRM relative dose equivalent rate roughly doubles, for both the northern and southern flights, between 33,000 and 41,000 ft (which agrees with the trend identified for the neutron fluence). Time-integrated route specific neutron dose equivalents were calculated for the various neutron dosimeters based upon the different spectra (Table C). The LCRM recorded twice the counts of the plain rem-meter for both routes, and both detectors recorded 18% higher counts for the northern, higher-altitude route.

To determine the neutron dose equivalent, the response of the detectors to both the TRIUMF and PuBe spectra were considered. The ratio of the counts of the LCRM to plain rem-meter is ~2.2 for both flights, which is in agreement with the calculated LCRM<response predicted ratio as calculated by convoluting the rem-meter response with the Hess spectrum.

4.2. Bubble Detector (BD). The BD measurements indicate that the neutron dose equivalent was distributed uniformly inside the aircraft on both routes. The average route specific BD measurements are also shown in Table C. For the TRIUMF calibration factor, the BD gives a smaller dose equivalent than that measured by the LCRM, but they are in agreement to within experimental uncertainty. When convoluted with the Hess calibration factor, the BD measurements agree with the results obtained by using the TRIUMF calibration factor. The latter observations suggest that the BD is not responding to the higher energy neutrons (i.e., 100 MeV peak) as might be expected since the neutron cross sections decrease at higher energies[14].

5. Total Dose Equivalent. The total dose equivalent was calculated for each route by summing the low LET results (IC measurements) with the neutron results (BD or LCRM) (Table D).The response of the BD and LCRM to fast protons will be investigated at TRIUMF (up to 500 MeV). Using our current calibrations, the BD+IC results are lower than the LCRM+IC results by roughly 35%, which is within experimental uncertainty. The percent neutron contribution for the BD+IC and the LCRM+IC being 58% and 74%, respectively (see Table D).

A calculation of the total equivalent dose for the Köln-to-Trenton flight, as predicted the Federal Aviation Administration code, CARI-2, (which calculates the total dose equivalent on any great circle route) yields a value of 43 μSv. Assuming that neutrons would provide roughly 50 % of the total dose equivalent, then the individual LCRM and BD measurements yield a total dose equivalent between Köln-to-Trenton of 90 μSv, and 48 μSv, respectively (for a TRIUMF calibration factor). These estimates are comparable to the total dose equivalents calculated using the TRIUMF calibration factors (see Table D). Since CARI-2 is consistent with the BD and LCRM to within experimental uncertainty, the BD can be expected to yield a reasonable estimate of the total dose equivalent. This methodology was therefore employed for the survey phase of the study as discussed in section III.B.

B. Survey Phase

Over 50 pilots participated in a survey in which BDs were used during their normal flight duties. After each flight, the pilots recorded the bubble count, temperature and altitude history. The counts were converted to neutron dose equivalent based upon the method derived in the measurement phase. Us;ng a correlation between the time averaged altitude for each flight and the percent neutron contribution6, the total dose equivalent was derived by dividing the measured neutron dose equivalent by the fraction of neutrons present at the averaged flight altitude. The result was then grouped to give the route, or mission specific, total dose equivalent. The annual contribution was determined by scaling the route specific total dose equivalent to reflect the typical pilot's mission profile as derived from squadron pilot logs and flight frequency information (Fig. 4).

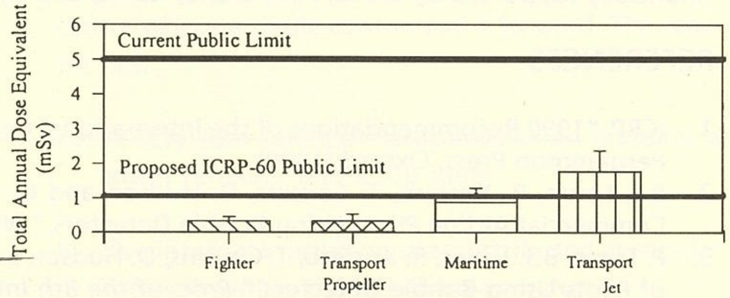

Fig. 4 Canadian Forces pilot annual total dose equivalent by squadron.

As shown in Fig. 4, jet pilots are below the limit of 5 mSv/y for the general public, and slightly above the proposed ICRP-60 public limit of 1 mSv/y. This observation is valid even if the results are scaled in accordance with the higher LCRM+IC results, with the exceptions being that typical transport propeller pilots may just, and maritime pilots will, exceed the 1 mSv/y limit. In general, the fighter pilots did not spend a prolonged time above 30 000 ft and therefore do not exceed 1 mSv/y.

IV. SUMMARY

1. For the dedicated flights of the measurement survey, the IC and TLD results compare favourably with each other, which suggests that both can be used to monitor the high-altitude ionizing radiation exposure. Although the LCRM and BD results agree within experimental uncertainty, there is a concern about the absolute calibration of both devices (see section III.4). It is expected that this issue will be resolved by further experiments at TRIUMF and DREO and when spectral information and improved calculations of the response functions become available. In the present study, the neutron component lies between 56% to 71% of the total dose equivalent (i.e., for the sum of the low LET and neutron measurements) (see Table D). Furthermore, the LCRM+IC results indicate that approximately 20% more total dose equivalent was received on the northern flight route compared to the southern route. The survey phase indicates that, for 1994-95, the participating CF pilots did not exceed the current 5 mSv/y limit for the public and only the transport jet pilotswere slightly above the proposed ICRP-60 public limit.

ACKNOWLEDGMENTS

The author would like to acknowledge the participation and expert advice of T. Cousins, T.A. Jones, B.E. Hoffarth and J.R Brisson (from the Space Systems and Technology Section, Defence Research Establishment Ottawa); P. Goldhageny A. Cavallo, W. Van Steveninck, M. Reginatto, P. Shebell and F. Hajnal (from the U. S. Department of Energy, Environmental Measurements Laboratory); and T. Jamieson and F.J. LeMay (from Science Applications International Corporation Canada, Ottawa). I am grateful for the support and interest of the CF Air Command, the Command Surgeon and Wing Surgeons; participating CF Aircrew from Wings at CFB/BFC Bagotville, Cold Lake, Comox, Greenwood and Trenton; Operations Research Division from the Transport, Maritime and Fighter Air Groups; AETE, CFB Cold Lake; and Dr. K. O'Brien for his invaluable advice and CARI- 2 calculations. This research was financially supported by CRAD, ARP, DGNS, NDHQ and by the U.S. DOE.

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Leu-Fuelled Slowpoke-2 Modelling with MCNP4A [1]

J.R.M. Pierre [2]

Introduction

Following the commissioning of the Low Enrichment Uranium (LEU) Fuelled SLOWPOKE-2 research reactor at Royal Military College-College Militaire Royal, excess reactivity measurements were conducted over a range of temperature and power. The results showed a maximum excess reactivity of 3.37 mk at 33°C (the measurements were taken at 10W, and the temperature was attained by heating the reactor pool, therefore it can be assumed that the reactor temperature was uniform)(l). First calculations showed a maximurn excess reactivity occurring at 12°C, and the calculated absolute values of the excess reactivity was off by a much greater margin. Further calculation and simulation were performed by Robert T. de Wit (2). Although no significant progress could be obtained on the temperature trend, the absolute value was improved but remained off by several mk.

École Polythecnique de Montreal also attempted to simulate the temperature trend for their research reactor. The data taken out of C. Guertin's thesis (3) successfully reproduced the temperature trend but produced of a less accurate excess reactivity value.

Given the advance in computer technology, the use of Monte Carlo N-Particle Transport Code System MCNP 4A (4) is now possible for the simulation of the LEU-fuelled SLOWPOKE 2 core at 20 degrees Celsius and hopefully for the reproduction of the correct temperature trend.

The code

MCNP 4A is a full three dimensional programme allowing the user to enter as much complexity as required. The limit on the geometry complexity is the computing time required to achieve a reasonable standard deviation. To this point several models of the SLOWPOKE-2 have been developed giving some insight on the sensitivity of the code. MCNP4A can use various cross section libraries. At this time, all models have been based on the ENDF/B-V library as it is the most complete one available on site. For light water and heavy water, material cards have also been used (LWTR.OIT and HWTR.OIT).

Geometry

The main problem when simulating the SLOWPOKE-2 reactor at RMC-CMR is the lack of symmetry and its small size (Figure 1). The core is composed of 198 fuel rods distributed to maximize the neutron flux on the periphery where the irradiation sites are located. It was also designed to have a relatively high flux at the centre where a single control rod is located. The reactor has:

A. A beryllium reflector composed of an annulus, a lower reflector and a top shim;

B. five internal irradiation sites distributed at regular intervals within the beryllium anmulus;

C. One large outside irradiation site in the water of the reactor container, between the beryllium reflector and the container wall;

D. Two small outside irradiation sites in the water of the reactor container;

E. One cadmium lined irradiation site again in the water of the reactor container;

F. A thermal column (not represented in Figure 1);

G. The control rod located at the centre of the reactor.

1) Winning paper, Masters Category, 1996 CNA/CNS Students Conference. 2) Department of Chemistry & Chemical Engineering, Royal Military College.
3) Supervisor: Dr. H.W.J. Bonin

H. Several structural devices holding these components together (not represented in the simulation); and

I. the reactor container vessel.

The model

The aim of this work is to calculate accurately the reactivity of the core and reproduce the temperature trend of the reactivity. The model preserved as much as possible the details of the core and facility in order to allow further study in flux mapping.

The main advantages of this model as provided by the Monte-Carlo approach are:

A. All the reactor components and the reactor as a whole were modelled in three dimensions;

B. The 198 fuel pins were located according to the drawing AL82245, and reference 5, therefore reproducing a heterogenous model. Each of the fuel pin was modelled accurately, including the gap between the fuel pellets and the cladding;

C. Although simplified, the control rod was modelled with the dimension of the cadmium conserved;

D. All the irradiation sites were modelled by cylinders of appropriate material and size;

E. The reflector was modelled in accordance with the appropriate drawing but the holes containing the irradiation sites were simplified;

F. The thermal column was included in the model;

G. Although simplified, the reactor container was modelled in its entirety; and

H. The pool was modelled up to the stainless steel liner.

Results

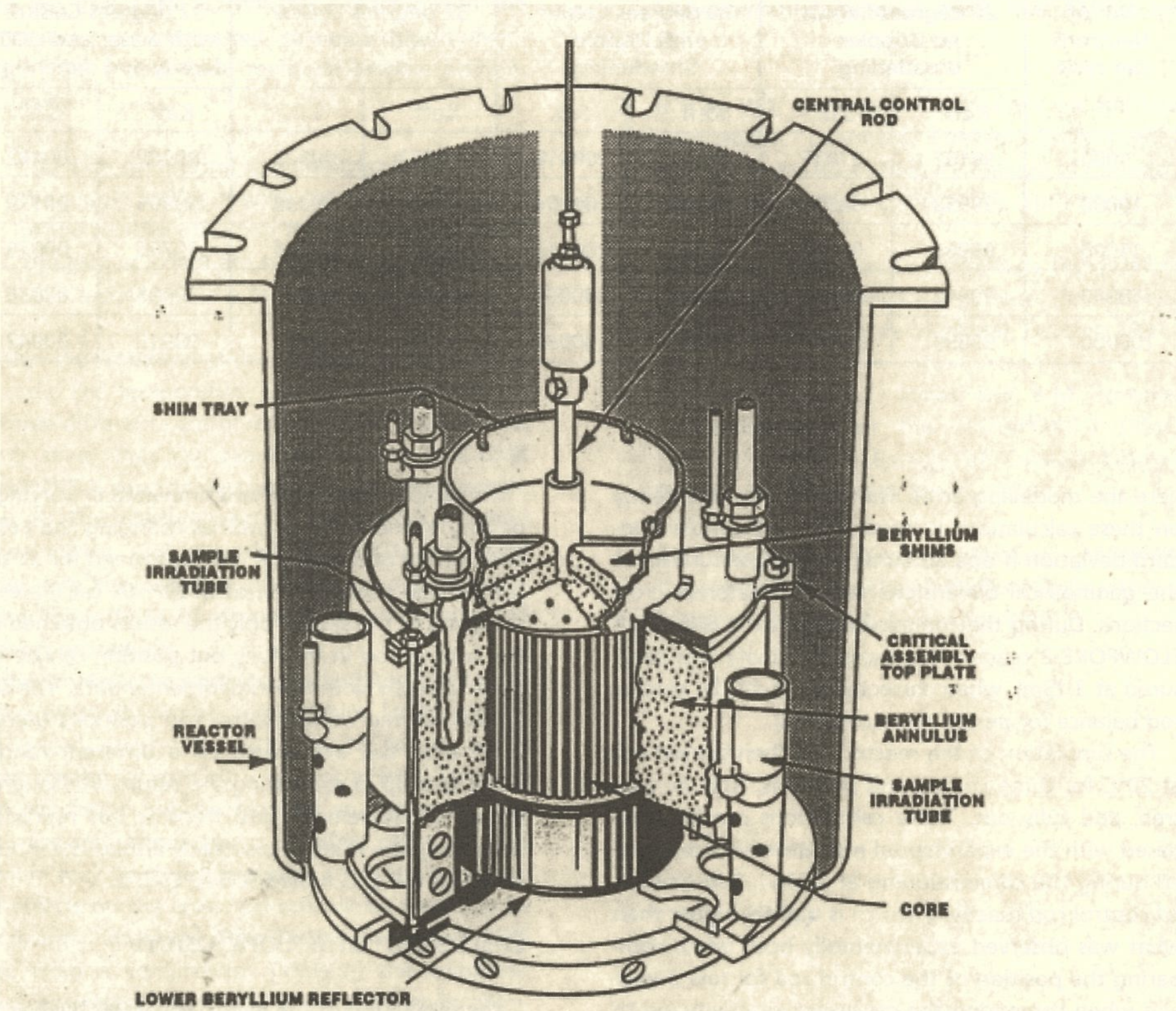
The results obtained so far can be divided in three groups, the reproduction of the excess reactivity at 20°C, the simulation of the control rod positioning, and the reproduction of the temperature trend.

Two models were used to calculate the excess reactivity at 20°C: first the control rod was located in its fully out position, and secondly it was completely replaced by water. These models yield respectively 3.17mk with a standard deviation of 0.2mk and 3.85 mk with a standard deviation of 0.19mk for the excess reactivity. The standard deviation does not include

TABLE I: CONTROL ROD REACTIVITY WORTH

	Reactivity (mk)	number active cycles	number neutrons / cycle	1 Standard deviation (mk)	2 Standard Deviations (mk)
Control Rod Position (from bottom reflector)	Simulation				
Fully out (20.32)	3.17	180	$1x10^5$	0.2	0.4
Centred (10.16 cm)	-0.79	410	$1x10^5$	0.14	0.28
Fully inserted	-4.68	100	1.10^5	0.26	0.52
Control Rod Worth	7.85mk	0.33	0.66		
Experimental Data					
Estimated Control Rod Worth (reference 1) (mk)					5.45
Control Rod Position for 0 excess reactivity and low Power (reference 34) (from bottom reflector)					6.86 cm

Figure 1



SLOWPOKE-2 Reactor Core

TABLE II: TEMPERATURE EFFECTS

No. of Neutrons per cycle	20 degrees Celsius no Doppler broadening		20 degrees Celsius with Doppler broadening		32 degrees Celsius with water density		32 degrees Celsius with water and UO2 density and dimension	
	Keff	S.D.	Keff	S.D.	Keff	S.D.	Keff	S.D.
1000	.99107	.01455	1.00518	.00418	.99422	.00523	.99907	.00482
10000	.99953	.00394	1.00066	.00154	.99508	.00148	.99805	.00139
15000	.99968	.00107	1.00033	.00112	1.00009	.00124	.99765	.00079
50000	.99942	.00068	.99921	.00059	.99888	.00067	.99803	.00056
100000	.99899	.00048	1.00021	.00030	.99916	.00042	.99916	.00042

here the modelling error. Therefore, the uncertainty on these calculations is larger than the simple standard deviation if one accounts for the inaccuracies in the geometrical dimensions and the materials cross sections. During the commissioning of the RMC-CMR SLOWPOKE-2 reactor the excess reactivity was measured at 3.15mk when corrected to 19.4°C by control rod balance (or period measurements).

The simulation of the reactor was then carried out at 20°C for three control rod positions, fully in, centred, and fully out. These calculations can be compared with the experimental measurements conducted during the commissioning at Table I. The simulated control rod reactivity worth is slightly higher than what was observed experimentally both when comparing the position of the control rod for low power and when comparing the calculated reactivity worth with the experimental evaluation. The discrepancies may be explained by these most likely factors:

A. Geometry error: the actual location of the control rod in the core may not be duplicated in the model accurately enough,

B. Material error: the cross sections libraries used may not be sufficiently accurate;

C. Statistical error: the control rod may not be sampled adequately.

The temperature trend was simulated by varying the density of the water as well as changing the volume and density of the $U0_2$. It was performed for all three control rod positions. Since MCNP 4A calculates the reactivity of the system only the results obtained with the control rod in the fully out position can be compared directly with the experimental data. The simulations for the other control rod positions used the same scale but are placed on a different range in order to help in comparing the results. Although the shape of the temperature trend is not reproduced accurately, the simulations clearly display the inherent safety of the LEU fueled SLOWPOKE-2.

Discussion and Conclusion

The simulation of the RMC-CMR SLOWPOKE-2 reactor by Monte-Carol method was successfully accomplished using MCNP 4A. The main advantages of MCNP 4A were the ability to model the entire reactor in three dimensions and the ability to use transport theory instead of the limiting diffusion calculation. These advantages lead to significant improvement in reproducing the experimental excess reactivity of the RMC-CMR SLOWPOKE-2 reactor.

MCNP4A also allowed the modeling of the unique control rod in different positions, permitting the calculation of the reactivity worth of the control rod. Although the simulation overestimated the reactivity worth, the discrepancy with the experimental data was less than 50 percent for this hard problem.

When the reproduction of the trend of the reactivity of the RMC-CMR SLOWPOKE-2 reactor with the temperature was attempted, some of the disadvantages of the Monte-Carlo methods became evident, specifically:

a. The high computing cost involved in producing the highly precise results, required in the study of the relative effects of the temperature, and
b. The lack of adequate treatment for modifying cross sections for the temperatures of interest.

Within the limitation of the computing facilities and the code, the temperature trend was simulated for the three different control rod positions. These curves clearly show that the reactivity of the RMC-CMR SLOWPOKE-2 reactor decreases as the temperature increases. The inherent safety of the reactor is indeed demonstrated, and provides the MCNP 4A-based model with the potential of being used for investigating the effects of proposed modifications and licensing procedures.

Unfortunately, the experimentally-determined peak of the reactivity versus temperature could not be reproduced accurately with the MCNP 4A-based model for the SLOWPOKE-2 reactor at RMC-CMR. No hard conclusion can be reached at this point, but there are indications that a possible cause for this problem may be the representation of the temperature effects on the cross sections, which needs to be significantly improved. The results presented here come from a compromise between the computer resources presently available and the quest for minimizing the standard deviations through larger number of cycles and histories. With more performing computers and improved Monte-Carlo methods just around the corner, the problems encountered in this studies may soon be resolved.

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Extraction of Iodine from Environmental Surplus [1]

Mark D. Ho [2]

ABSTRACT

Environmental radioiodine is currently gaining acceptance as a tracer for studies of groundwater flow, radioactive contamination, and many other environmental applications. To speed and to simplify preparation of organic and inorganic environmental samples for analysis, a microwave acid digestion technique combined with a sulphide co-precipitation step holds promise, if a good recovery yield is attainable. A consistent procedure was developed, and standard samples of known iodine content were processed in this way, to evaluate recovery effectiveness.

The acid digestion process is only partially successful, and sample losses during transfer steps can be significant. Meanwhile, a radiotracer experiment showed that full recovery in the precipitation step is easily achieved. Epithermal instrumental neutron activation analysis (EINAA) was used to assess total iodine content in both treated and untreated samples, and to establish background contamination in reagents and experimental apparatus. Preliminary results indicate good reproducibility in analysis, but also possible contamination in the precipitating agents. These results are currently being verified.

INTRODUCTION

Iodine is a biologically active element, potentially important to population and ecological health. Environmental radioiodine is produced naturally by atmospheric cosmic ray bombardment, and artificially as nuclear fission products of U and Pu. The latter source comprises primarily nuclear weapons testing and fuel reprocessing, although the Chernobyl incident of 1986 also released massive quantities of radioactive iodine into the atmosphere and around the world. The most important isotopes of iodine are the sole naturally-occurring and stable ^{127}I, and the radioactive ^{129}I ($t_{1/2}$ = 1.57 x 10^7 a), and ^{131}I ($t_{1/2}$ = 8.0 d). The ^{129}I and ^{131}I are among the more abundant nuclear waste products and also more likely to have an impact on the environment, the first due to its longevity, and the second due to its very high specific activity. For long-term environmental measurements, the extremely long-lived isotopes including ^{129}I are increasingly used.

The comparative isotopic ratio of ^{129}I to ^{127}I is used as a measure of ^{129}I content in a sample. As with radiocarbon, nuclear testing in past decades has shifted the ^{129}I / ^{127}I proportions found in nature. Currently accepted values range from pre-nuclear ratios on the order of 10^{-12} to 10^{-15}, up to 10^{-9}. Contamination is indicated when ratios exceed 10^{-8}, and values of 10^{-5} have been observed in severely contaminated samples. At these higher levels, ^{129}I analysis falls within the reach of radiochemical neutron activation analysis (RCNAA), where post-irradiation techniques are employed to concentrate the iodine and to remove interfering isotopes. However, lower levels fell below the minimum detection limits for consistent quantitative determinations until the advent of accelerator mass spectrometry (AMS) in 1981.

At such low levels, interference from the biological or geological sample matrix, or other elements present, will limit the sensitivity of any analytical method. The objective of this project is to evaluate and to quantify the effectiveness of a technique to preconcentrate and extract iodine from environmental samples, primarily organic and inorganic solids such as soil or vegetation. To separate iodine out of the solid component for chemical processing, basic digestion, acidic digestion, and extraction rinses have variously been used. Microwave acid digestion is a simple, yet rapid and inexpensive method for sample preparation, with lower risk of sample contamination. Once in a liquid state, iodine species are extracted by precipitation as insoluble iodides such as AgI, or by trapping the iodide within a scavenging co-precipitate compound. The latter method, using a sulphide collector matrix, has been deemed more effective, and will be used in this project (Rao and Chatt, 1991). The collected precipitate is then analyzed instrumentally for iodine content.

Standard samples of known iodine content will also be carried through the proposed process as indicators of stepwise and of overall recovery. While an eventual objective is to determine the content of ^{129}I in the samples, only the stable ^{127}I, which comprises very nearly all of the total iodine, may be directly measured by instrumental neutron activation analysis

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1) Winning paper, Undergraduate category, 1996 CNA/CNS Student Conference. 2) Department of Chemical Engineering and Applied Chemistry, University of Toronto. 3) Supervisor: Prof. Greg J. Evans

(INAA), which will be the primary analytical tool. If the overall recovery and purity of the total iodine is high, this extraction method may be suitable for preparing lower level environmental samples for AMS analysis as well. If it proves feasible, the method can also be easily extended to handle samples of all phases, including aerosol samples collected on solid filters.

LITERATURE SURVEY

MICROWAVE DIGESTION

The use of microwave energy to heat an acid digestion mixture in a pressure vessel is a relatively new technique. It has successfully been used in multi-element, flame atomic absorption spectroscopy (FAAS) and inductively coupled plasma atomic emission spectroscopy (ICP-AES) determinations of trace elements in organic samples (Nakashima *et al,* 1988). The primary benefits of microwave acid digestion over the more conventional high-temperature ashing, are speed and convenience. Less handling and transfer of the sample is required, decreasing the possibilities for losses and contamination. The most limiting factor in the use of microwave digestion vessels is the difficulty of maximizing digestion efficiency, which is also restricted by the maximum attainable digestion pressure and temperature (Kingston and Jassie, 1988).

The work by Rao and Chatt (1991) uses nitric acid digestion to extend this technique to iodine in organic samples. However, some iodine-specific problems must be resolved, especially its volatility. This property can be controlled by the addition of LiOH (Muramatsu *et al.,* 1988) or by refrigeration and using reducing agents such as hydrazine sulphate (Rao and Chatt, 1991) to form soluble, non-volatile iodide.

EXTRACTION AND DECONTAMINATION

At the University of Toronto IsoTrace AMS Laboratory, an alkali fusion process is now used for soil and sediment sample preparation, adapted from the dry ashing procedure previously employed. A sample of 2 to 5 g is mixed with an excess of NaOH and Na_2O_2, then heated according to a predetermined temperature schedule, over 54 hours. The addition of $NaNO_2$ promotes the formation of coloured I_2, which may then be separated by liquid-liquid extraction with CCl_4. At this point, the further addition of $NaHSO_3$ will back-extract the I_2 into the aqueous phase as to colourless I-. Silver nitrate is added, precipitating out AgI, which is then sintered into target plates for AMS analysis (Dr. L.R. Kilius, pers. comm.).

For NAA, bismuth compounds are preferred as precipitation agents, instead of the silver, due to the much lower neutron activation sensitivity of the former. The bismuth can be quantitatively co-precipitated by several different agents, with sulphide ion in 0.2 M acidity being the most effective combination of those tested by Rao and Chatt (1991).

NEUTRON ACTIVATION ANALYSIS

Epithermal instrumental neutron activation analysis (EINAA) uses a neutron absorber such as B or Cd to shield samples from the full neutron flux in the reactor, restricting irradiation to neutrons of greater than thermal energies. This step is necessary when analyzing for low levels of iodine, to reduce interferences from easily activated Al, Mn, K, and Na. At the University of Toronto SLOWPOKE-2 Reactor Facility, Cd shielded irradiation vials are available. However, a dedicated, boron-shielded epithermal irradiation site, as installed in the Dalhousie University SLOWPOKE-2 Reactor is ideal (Rao and Chatt, 1991).

Muramatsu et al. (1988) were able to directly measure ^{126}I ($t_{1/2}$ = 13 d) and ^{130}I ($t_{1/2}$ = 12.3 h), after a six-hour long, high-flux thermal neutron activation of a highly purified sample extract, relying more on additional post-irradiation solvent extraction steps to boost the decontamination. Unfortunately, typical environmental concentrations of ^{129}I are probably not directly detectible by current INAA or EINAA techniques at Toronto SLOWPOKE. The maximum reactor power is insufficient to use thermal irradiations, while the Cd shielding is not amenable to low power, overnight irradiations. AMS may be the only local means available for ^{129}I measurement.

ACCELERATOR MASS SPECTROMETRY

This technology, which has already greatly advanced the range and accuracy of radiocarbon dating, allows the counting of individual atoms in a modified mass spectrometer system. Electrostatic and electromagnetic separation of atoms and molecular fragments of similar mass in a tandem accelerator removes these interferences, permitting resolutions approaching one part in 10^{15} (Rucklidge, 1995). Recent studies by AMS have included the aquatic and terrestrial environments surrounding the nuclear reprocessing facilities at Sellafield, UK (Kilius *et al.,* 1994), and Hanford, Washington (Rucklidge *et al,* 1994). The use of AMS in ^{129}I measurements was also demonstrated in the Arctic Ocean, tracking contamination from reactor dumping grounds in the former Soviet Union (Raisbeck *et al.,* 1993).

MATERIALS AND METHOD

Standard samples of known iodine concentration and content were analyzed using the described extraction method (see **Figure 1**). Certified NBS (NIST) Standard Reference Material #1571 (Orchard Leaves) and #1646 (Estuarine Sediment) were used, containing 100-220 ppb, and 32500 to 36000 ppb respectively, in iodine (U.S. NBS Publication, 1987). A sample of IAEA Standard #375 was obtained to aid in determination of iodine recovery. This soil sample, well quantified in many elements and fission products, including ^{129}I, was part of an original 500 kg of topsoil taken in 1990, from the first 20 cm layer from a farm in the Brjansk region of Ukraine, near the Chernobyl accident site. Iodine has great adsorptive affinity in soil matrices, and should readily collect, and be found in these top layers. A 1000 ppb NaI solution and a 500 ppb KIO_3 solution were also prepared for NAA calibration and additional verification.

A simplification of the preconcentration method used by Hammad (1994) was adopted. A Parr Model 4782 45 mL microwave digestion bomb was used for sample digestions. In these experiments, bomb charges of 50 mg up to 200 mg were used, all in 3.0 to 5.0 mL of BDH concentrated standard reagent grade nitric acid, with more acid being used for soil samples. The sealed bomb was heated in a commercial 550 W General Electric microwave oven, with heating times at full power restricted to a maximum of 45 seconds, to prevent overpressurization of the digestion vessel. The bomb was cooled in a cold water bath until it was safe to open, before the digested sample was removed.

In many cases, digestion was not complete, and two or three additional heating cycles of 45 seconds were ineffective. Samples were mostly dissolved, but some particulate always remained, and adhered to the Teflon cup walls. The sample was transferred as best as possible, with multiple rinsings of high-purity (>17 M -cm) water into a beaker for precipitation. Partial digestion had already accomplished considerable sample preconcentration, and the undigested portion of the sample matrix, was also be captured in the precipitate.

Rao and Chatt (1991) determined the minimum amounts of precipitation reagents required for quantitative recovery in a 100 mL solution at 0.2 M acidity were 5 mg of Bi^{3+} and 4.3 mg S^{2-}, but recommended 40 mg Bi^{3+} and 8.5 mg S^{2-}. Reagent (both Mallinckrodt) solutions were prepared at 32 mg Bi^{3+} / mL and 10 mg S^{2-} / mL respectively. The bismuth was

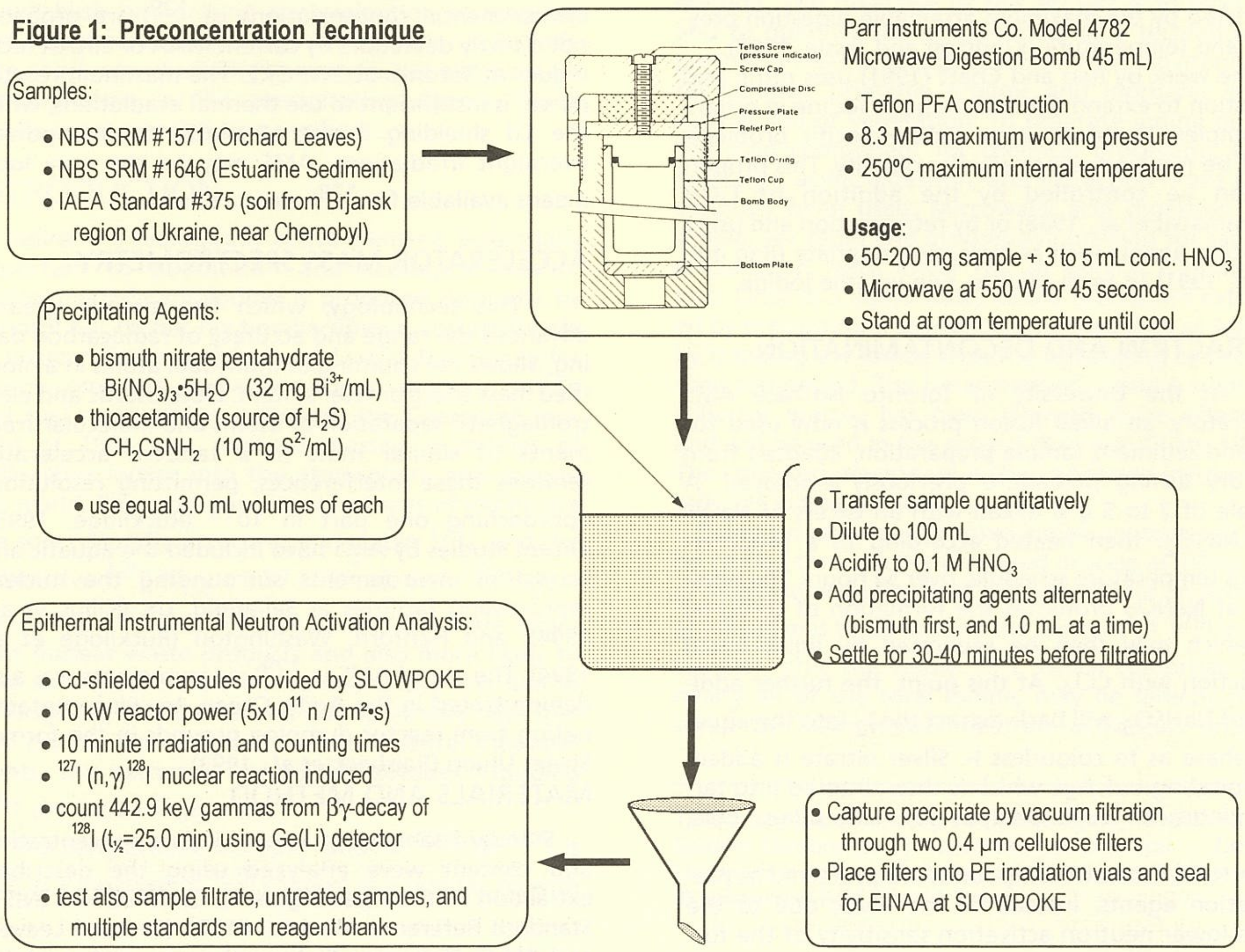

Figure 1: Preconcentration Technique

still insoluble at the concentration made, and was well shaken each time before extracting for use. The precipitation step involved diluting the sample to approximately 100 mL, and adding 1 mL HNO_3 to acidify to about 0.1 M, then adding equal 3.0 mL volumes of the bismuth nitrate and thioacetamide reagents alternately, 1.0 mL at a time, gently swirling the sample solution instead of using mechanical mixing.

When the thioacetamide is added, a dark brown-black coloured Bi_2S_3 precipitate forms over a period of minutes:

$$CH_3CSNH_2 + 2\,H_2O + H+ \longrightarrow CH_3COOH + H_2S + NH_4+ \quad (1)$$

$$H_2S \longrightarrow H^+ + HS- \quad (2)$$

$$Bi_2S_{3(S)} + 3\,H_2O \longrightarrow 2\,Bi^{3+} + 3\,HS- + 3\,OH- \quad (3)$$

$$K_{sp} = 1.6 \times 10^{-72} \text{ (Chang, 1991)}$$

The iodine is co-precipitated with the Bi_2S_3.

After a room temperature settling period of approximately 30 minutes, the solution was filtered. An insufficient delay does not allow complete nucleation, and the precipitate passes through the filters. If the delay is too long, there is significant adhesion of precipitate to the glassware. The filtration unit, with glass and ceramic joints sealed with petrolatum, used Millipore Corp. HA type cellulose filters, of 0.4 m pore size, and 25 mm diameter. Filter breakthrough by the sample was eliminated by the use of two layers. The unit was placed on top of a 125-mL double-thickness vacuum flask connected to an aspirator, providing filtration flow rates of approximately 0.5 mL per second.

When fully drained, the filters were placed in standard 1.2 mL polyethylene irradiation vials and heat sealed. EINAA was performed, using ten minute epithermal irradiation at a neutron flux of 5×10^{11} neutrons/cm²-s. During irradiation, the ^{127}I in the sample undergoes a (n,) nuclear reaction to form ^{128}I ($t_{1/2}$ = 25.0 min), which was measured over a ten minute counting period by monitoring the gamma energy at 442.9 keV produced by its -decay to ^{128}Xe. Decay times before counting were usually under ten minutes, as the Cd shielding effectively prevented much of the interfering activity from Al, Mn and Na. All standards and untreated samples were similarly analyzed. To assess iodine contamination, reagents and blank samples were also analyzed. For certain samples with known high iodine content, the reactor flux was reduced to 1×10^{11} n/cm²-s. Common reference samples were re-analyzed at each NAA session, as quality assurance monitors between separate irradiation runs (Prof. G.J. Evans, pers. comm.).

A ^{131}I radiotracer study was conducted to estimate the precipitation/filtration recovery obtained with increasing volumes of each reagent (See **Figure 2**). Three 10 µL tracer spikes were carried through the precipitation and filtration procedure, using 1.0 mL, 2.0 mL, and 3.0 mL volumes of each precipitating agent. Final extract activities were counted using a 50% efficient NaI liquid scintillation counter, running a preconfigured 300 second iodine analysis program. Results were compared to a fourth tracer spike, used as a control.

It is anticipated that liquid samples such as lake water may proceed without digestion, directly to the iodine precipitation stage. To estimate the applicability to seawater samples, a 100 mL solution of 0.5 M NaCl containing a 2 µg spike of I- was carried through the precipitation procedure. Unfortunately, the excess amounts of precipitation agents caused the formation of significant amounts of $BiCl_3$. The Cl cannot be separated by filtration, and greatly interferes with neutron activation analysis.

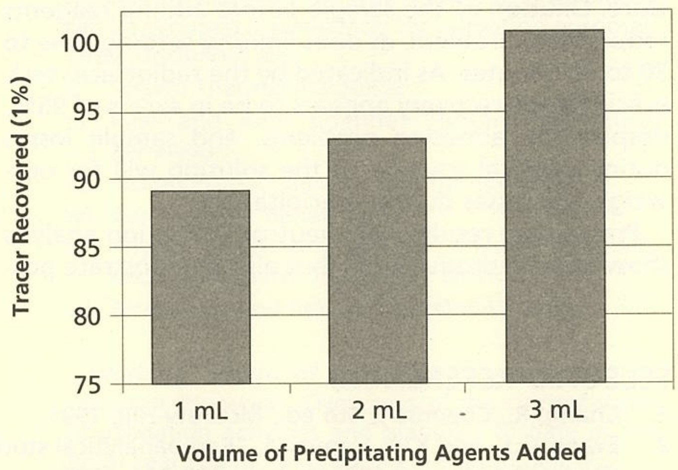

Figure 2:
Effectiveness of Iodine Co-precipitation Step

PRELIMINARY RESULTS AND DISCUSSION

Complete sample digestion was difficult to achieve, even after repeated heating. The liquid portions of the orchard leaves samples were cloudy and yellow with particulate. Similar problems were encountered with the IAEA soil, and the estuarine sediment could not be satisfactorily liquified. However, when acid from a newly opened bottle of J.T.Baker concentrated HNO_3 was used, sample digestion was much more vigorous and complete. The original acid may have become diluted or contaminated over time.

Quantitative sample transfer is difficult to guarantee, and losses during each transfer step can be sig-

Table 1: Preliminary NAA Results

	Measured Iodine (ppb)	Literature Value (ppb)
IAEA 375 Brjansk Soil	1730 ± 250	1360 ± 120†
Treated IAEA375	1940 ± 500	–
NBS 1571 Orchard Leaves	220 ± 45	100 - 220

† from Muramatsu and Yoshida (1995)

nificant. For instance, particulate adhesion to the internal Teflon walls of the digestion bomb cannot be completely remedied by rinsing with deionized water, and Rao and Chatt (l991) required the use of 5% hydrazine sulphate. The brown-black bismuth sulphide precipitate also stains and adheres to glassware. Dilution of the sample before adding reagents reduces this problem, as does limiting settling time to 30 to 40 minutes. As indicated by the radiotracer test, precipitation recovery appears to be in excess of 95%, despite the adhesion problems, and sample losses during physical transfer of the solution will far outweigh any losses during precipitation.

Preliminary results from neutron activation analysis show good reproducibility, but also demonstrate possible contamination in the precipitating agents, which would invalidate any conclusions which can presently be drawn. Current efforts are focused on verifying all NAA results, and on eliminating the source of contamination, if it exists.

ACKNOWLEDGEMENTS

The author wishes to thank Prof. G.J. Evans of the Dept. of Chemical Engineering and Applied Chemistry, for his patient supervision and guidance throughout this research, and also Dr. L.R. Kilius, and Prof. J.C. Rucklidge of the IsoTrace Laboratory for their additional insight and advice, and for generously providing a sample of IAEA Standard #375. The invaluable assistance provided by Prof. R.G.V. Hancock and S. Aufreiter of the SLOWPOKE Reactor Facility is greatly appreciated.

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Generic Validation of Computer Codes

for Safety Analyses of CANDU® Power Plants

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Abstract

Since the 1960s, the CANDU® industry has been developing and using scientific computer codes, validated according to the quality-assurance practices of the day, for designing and analyzing CANDU power plants. To provide a systematic framework for the validation work done to date and planned for the future, the industry has decided to adopt the methodology of validation matrices, similar to that developed by the Nuclear Energy Agency of the Organization for Economic Co-operation and Development for Light Water Reactors (LWR). Specialists in six scientific disciplines are developing the matrices for CANDU plants, and their progress to date is presented.

1. Introduction

Since the 1960s, the CANDU industry has been engaged in the development and validation of safety-related computer codes. The codes have been used in support of safety analyses of CANDU reactors, and in some instances to assist in the planning and understanding of experimental work done at the laboratories. The focus of the industry's validation approach was to gain knowledge through experimental and theoretical studies and implement that knowledge in mathematical models that are validated, to the extent possible, in separate-effects tests. The models were then installed in computer codes that are tailored to meet current quality assurance practices of reliability and user friendliness, and the codes were validated against integrated tests.

During the fifteen years leading up to 1990, there was an intense effort on code development and validation to support the CANDU reactors in operation and those under development. The task of code validation was supported by an R&D program, presently known as the Safety and Licensing R&D Program of the CANDU Owners Group (COG). The program was jointly funded and reflected the interests that were common to the three Canadian utilities operating CANDU power plants (Ontario Hydro Nuclear (OHN), Hydro Quebec (HQ), and New Brunswick Power (NBP)) and Atomic Energy of Canada Limited (AECL).

Since 1990, the R&D has become more focused on ensuring that code validation is carried out to satisfy both the needs of the industry, for its current design activities and plant operations, and the demands of the regulators. The R&D programs are reviewed both by COG Technical Committees and in-house by AECL. In 1995 June, the industry formed a Code Validation Team, to coordinate code-validation activities in the four partner organizations (OHN, HQ, NBP, and AECL). More recently, the Validation Team has been restructured into a Steering Group and several Working Groups. Building upon work initiated at Ontario Hydro Nuclear, the Team's focus is the generic validation of the major codes used in safety analyses of CANDU reactors in operation and those under development. Generic validation refers to those activities that are code independent and provide the knowledge base necessary for the systematic validation of specific codes, as explained further in Section 3. One of the Team's first outputs was agreement on six main disciplines into which physical phenomena can be grouped conveniently for validation purposes. These disciplines are:

i) System Thermalhydraulics;
ii) Fuel and Fuel Channel Thermal-mechanical Behaviour;
iii) Fission Product Release and Transport;
iv) Containment Behaviour;
v) Physics (comprising reactor physics, shielding, and atmospheric dispersion); and
vi) Moderator and Related Thermalhydraulics.

Working Groups of specialists in each discipline carry out the work. Overviews of the current status of validation activities and planning to date in this multi-year validation program are given below.

2. Formal Approach to Validation

While the industry's traditional approach to code validation, as outlined in the Introduction, has been in line with international practice, recent develop-

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ments domestically and internationally have provided the stimulus for a re-examination. Increasingly, the CANDU industry and its regulators expect computer codes to be formally validated within a systematic framework that can be readily audited. Such a framework exists, and its foundations are validation matrices. The Nuclear Energy Agency of the Organization for Economic Co-operation and Development (OECD/NEA) has recently published [1] validation matrices for LWRs that represent an international consensus in the LWR community on (i) the major, hypothetical accidents, (ii) physical phenomena that might occur during these accidents, (iii) experimental facilities, and (iv) data from separate-effects experiments suitable for the validation of computer codes used in safety analyses and licensing submissions. These matrices address thermalhydraulic phenomena in the primary heat-transport circuit, and for pressurized water reactors, also the secondary heat-transport circuit.

The CANDU industry has decided to utilize the validation-matrix methodology for its validation activities, and to adapt it as necessary, taking into account the state of the art internationally, available expertise, and cost/benefit considerations. Where no international precedents exist, the industry is proceeding with prudence. The steps are typically as follows:

i) identification of accident scenarios to be analyzed;
ii) identification and ranking of physical phenomena relevant to these accidents;
iii) description of the phenomena;
iv) identification of experiments that exhibit the phenomena;
v) description of the source facilities/tests; and
vi) generation of a cross-reference table of phenomena versus relevant experimental data.

The validation matrix comprises the tables in items (ii) and (vi) above.

The industry is examining its suite of safety-analysis codes, with a view to selecting the most appropriate ones for long-term development (if needed), application, and support. The validation matrices will provide the basis upon which to plan further code validation, if needed, to bring code development to closure. The above activities comprise a multi-year validation program, the front end, i.e. generic portion of which is described in the next sections.

3. Validation Matrices and Their Role In Code Validation

The validation-matrix methodology has five basic steps, illustrated in Table 1. In the first step, a Technical Basis Document is produced that provides a total overview of all postulated accidents in the design basis of the nuclear plant and the associated main physical phenomena governing the behaviour of plant systems and radionuclides. In the second step, validation matrices are produced for each discipline, relating all relevant physical phenomena to the relevant subset of accidents and to data from experiments, operating plants, mathematical solutions, and benchmark codes. Steps one and two provide the generic knowledge base which is code independent.

Steps three to five are code specific. In step three, a validation plan is produced for each code. The plan identifies validation work that is believed to be necessary to provide sufficient validation of the code for its intended applications. The execution of the plan demonstrates that the code version accurately represents the governing phenomena for each phase of the selected accident scenario. In step four, validation exercises are performed to compare model predictions with selected data sets. Uncertainties in code predictions are estimated.

In step five, a validation manual is produced, summarizing code accuracy, sensitivities, and uncertainties for specific applications. The manual addresses the question whether the validation is adequate.

While the validation methodology shows a linear progression through five steps, actual work is being performed in parallel, on steps one and two, and in all six disciplines, to maximize progress on as many fronts as possible and to engage specialists in all disciplines. The Steering Group ensures that the activities are coordinated and that experience gained is

Table 1: *VALIDATION METHODOLOGY*

(1)	Technical Basis Document	Relate safety concerns to main phenomena governing behaviour during each phase of specific accident.
(2)	Validation Matrices (6 in total)	Relate all relevant phenomena to accidents and data sets.
Generic (Code Independent) Knowledge Base		
Code Version Specific		
(3)	Validation Plan	Demonstrate that code version accurately represents governing phenomena for each phase of the selected accident scenario.
(4)	Validation Exercises	Compare model predictions with selected sets (uncertainty).
(5)	Validation Manual	Summarize code accuracy, sensitivities, and uncertainties for specific applications.

shared among participants. The achievements to date and the near-term plans are summarized in the sections below.

3.1 Technical Basis Document

Draft sections of the Technical Basis Document are being produced by specialists in the six disciplines, with some sections being in an advanced state of preparation and undergoing peer review. An example is the technical basis for analyses of large loss-of-coolant accidents (LOCA). The logic of that technical basis is illustrated in Figure 1, which relates the safety concerns, behaviours of plant subsystems and radionuclides, and main physical phenomena. Similar descriptions are being produced for other accidents in the design basis.

3.2 System Thermalhydraulics

A validation matrix for system thermalhydraulics has been developed that is based on the physical phenomena that might occur during accidents which form the design basis of CANDU power plants. Seven accident categories have been identified and addressed. They are: (i) large LOCA, (ii) LOCA with loss of emergency coolant (EC) injection (LOECI), (iii) small LOCA, (iv) loss of flow, (v) loss of regulation, (vi) loss of feedwater, and (vii) steam-line break. For this ensemble of postulated accidents, 23 phenomena have been identified, assigned an identification number from TH1 to TH23, and their relative importance during the different phases of the accidents has been estimated. That work has been summarized in a 23 x 7 matrix, an excerpt of which is illustrated in Table 2. For each of the seven accident scenarios, a table has been produced that divides the accident into a number of phases in the accident progression and identifies primary and secondary phenomena in each phase. Table 3 is an excerpt from the large-LOCA tabulation in which seven primary and three secondary phenomena have been ranked in four significant time phases. Similar rankings have been produced for the other six postulated accidents.

In the next step, relevant available tests, both experimental and numerical, were identified and tabulated.

Identification numbers were assigned to separate-effects tests (SE1 to SE25), component tests (CO1 to CO5), integrated tests (INT1 to INT17), and numerical tests (NUM1 to NUM10). An excerpt from this tabulation is illustrated in Table 4. At this point, the quality of the data was not judged; the data were simply identified as being potentially suitable and available for validation purposes. In the next step, the data were reviewed and assessed for suitability for code validation. One of three grades was assigned to each data set as it relates to each of the 23 thermalhydraulic phenomena: (i) not suitable, (ii) suitable for indirect validation, or (iii) suitable for direct validation. An excerpt from this tabulation is illustrated in Table 5.

To complete the generic part of the validation methodology, descriptions have been produced of the: (i) 23 phenomena, (ii) 37 experimental facilities, (iii) 25 separate effects tests, (iv) 5 component tests, (v) 17 integrated tests, and (vi) 10 numerical tests. The validation matrix comprises the two cross-reference tables: phenomena to postulated accident scenarios (illustrated in Table 2) and phenomena to tests (illustrated in Table 5).

Staff from the Atomic Energy Control Board (AECB) examined the validation-matrix document for system thermalhydraulics for CANDU power plants and discussed it informally with industry representatives. The staff's view was that the work done represents a significant advancement of generic validation, however, they expressed strong interest in the specifics in the validation plans for individual codes.

The industry's future work will focus on individual computer codes and their interface with the validation matrix. The partner organizations may opt to retain their preferred codes and to identify potential gaps, if any, in the data base and the possible need for additional code development and validation against selected tests from the data base. The specific tests will be selected to ensure that all phenomena that are likely to be encountered during an accident are addressed. The selection of these tests will be done on the basis of a thorough understanding of the thermalhydraulic phenomena and their rank or relative importance during a postulated accident.

TABLE 2: *EXCERPT OF THERMALHYDRAULIC PHENOMENA RELEVANT TO CANDU ACCIDENT ANALYSIS*

ID NO	PHENOMENON	ACCIDENT SCENARIO (7)		
		(1) LOCA	(2) → → LOCA/ LOECI	(7) STEAM LINE BREAK
TH1 ↓	Break discharge characteristics and critical flow	✓	✓	✓
TH12 ↓	Quench/Rewet characteristics	✓		
TH23	Noncondensible gas effect	✓	✓	

Although the focus of the above work was on CANDU safety analyses, the phenomena have broader applications to other thermalhydraulic systems such as research reactors and experimental loops.

3.3 Thermal-mechanical Behaviour of Fuel and Fuel Channels

The Working Group decided to construct the validation matrix in stages. The Group agreed that the initial data sets compiled for inclusion in the matrix would be those potentially suitable for validation of analytical tools used to assess channel-integrity concerns of large LOCAs.

Twenty three phenomena, representing all those expected to occur in any of the design-basis accidents, have been identified. In some cases, mutually dependent phenomena have been grouped and are represented by one observable process. This list has been cross checked for completeness for application to large LOCAs, via a detailed review of the relationships between safety concerns, parameters that are used to define margins for each safety concern, and the phenomena that determine the behaviour of each parameter. The latter information will represent the Group's contribution to the Technical Basis Document.

Synopses of all phenomena are being prepared. Initial definitions have been compiled, the task of preparing detailed descriptions has been distributed to Group members according to their area of expertise, and 14 descriptions have been produced. A preliminary ranking of phenomena, as either of primary or secondary importance, has been completed for each phase of the large-LOCA scenario. An initial draft list of 99 data sets has been compiled. Drafting of synopses for an initial selection of 30 of these is underway, with synopses of 29 of the in-reactor data sets completed. A draft matrix has been prepared that cross references the 23 phenomena to each of the 99 data sets. This initial correlation is based on preliminary expert judgment and still requires confirmation, following the preparation of data-set synopses.

3.4 Fission-Product Release and Transport

Due to the complexity and clear differences between the phenomena that control the fission-product release and the fission-product transport processes, for simplicity, the discipline was divided into these two sub-disciplines, and Sub-groups were formed in each. To avoid superposition, it is necessary to define the region of application for each sub-discipline. The following definitions have been adopted.

i) The Fission-Product Release sub-discipline includes all fission-product phenomena occurring in a fuel element up to the release of radionuclides via sheath failure.

ii) The Fission-Product Transport sub-discipline includes all fission-product phenomena occurring between sheath failure and release of radionuclides into containment.

Lists of 20 fission-product release phenomena and 23 fission-product transport phenomena have been produced. The lists of phenomena are under review by the team members and other members of the Canadian nuclear industry. Synopses that describe each of these phenomena and the identification of their key parameters are in preparation. As a trial case, the large LOCA combined with LOECI was selected for the phenomena-ranking process. The fission-product release phenomena were ranked as of primary or secondary importance with respect to their perceived impact on the amount of fission-product releases during a particular phase of the accident.

Preliminary identification of available experimental information on fission-product release indicates that the following tests are possible choices for the validation matrix: (i) 45 in-reactor tests, (ii) 200 in-cell tests, and (iii) 15 laboratory tests. Each test will be assessed to determine which phenomena occurred during the course of the test. This experimental data base includes experiments performed around the world. Some of these experiments, primarily in-reactor tests, were CANDU specific. The in-cell and laboratory tests have a wider application area.

TABLE 3: *EXCERPT FROM RANKING OF PHENOMENA FOR LARGE LOCA*

PHASE	POWER PULSE/REACTOR TRIP	EARLY BLOWDOWN COOLING	LATE BLOWDOWN COOLING/EC INJECTION	REFILL
Time(s)	0 - 5	5 - 30	30 - 200	>200
		PHENOMENA		
PRIMARY (7) ↓	Break discharge characteristics & critical flow.	Break discharge characteristics & critical flow.	Break discharge characteristics & critical flow.	Counter-current flow.
SECONDARY (3) ↓	Critical heat flux & post-dryout heat transfer	Critical heat flux & post-dryout heat transfer	Phase separation	Waterhammer

In the area of fission-product transport, identification of relevant validation data sets is in progress. The data sets for code validation will include experiments performed in Canada, e.g., laboratory aerosol-transport tests, hot-cell fission-product-transport tests, and in-reactor tests performed in the Blowdown Test Facility at the Chalk River Laboratories. The data sets for the validation of fission-product-transport codes will also include international separate-effects and integral experiments such as those from the PHEBUS-FP program. After appropriate tests have been identified, the data sets will be summarized and the uncertainties in the data will be quantified.

3.5 Containment Behaviour

The discipline was divided into the sub-disciplines of (i) Containment Thermalhydraulics and Hydrogen Behaviour, and (ii) Fission Product Chemistry and Aerosol Behaviour, and Sub-groups were formed in each.

The current status of the draft chapter for the Technical Basis Document is as follows. Postulated accident scenarios have been identified, and one is described in detail. Safety concerns for the chosen accident scenarios have been identified, described, and tabulated. Fundamental phenomena have been identified along the sub-discipline lines. Six phenomena have been described, as examples of the detail required for the final document. A table showing the relative importance of the phenomena for the accident scenarios has been produced.

The current status of the draft Validation Matrix Report is as follows. The available data base has been organized into categories, with 25 separate-effects tests, 13 integrated tests, and 7 numerical tests covering the areas of containment thermalhydraulics, hydrogen combustion, fission product chemistry, and aerosol behaviour.

An additional category, inter-code comparisons, is included, but no data sets have been identified because the benefit of this category to code validation is not clear at this time. Separate-effects tests, integrated tests, and numerical tests have been described briefly. Validation-base data sets and the number of individual tests in each set have been tabulated. The cross-reference table of the validation matrix that relates data sets to the phenomena identified in the Technical Basis Document has been prepared.

3.6 Physics

A Working Group has been assembled to define a validation matrix for the sub-discipline of reactor physics, seen as the area of high priority. While ad hoc validation work in the sub-disciplines of shielding and atmospheric dispersion of radionuclides is ongoing, it does not yet follow the validation-matrix methodology.

Preparation of the validation matrix for reactor physics is under way, and the steps outlined in Section 2 above are being followed.

In advance of the above work, AECL experts in physics produced preliminary documents on validation of physics codes, in all three sub-disciplines, that are in common use at AECL. These documents collect

TABLE 4: *EXCERPT OF SEPARATE EFFECTS TESTS, COMPONENT TESTS, INTEGRATED EXPERIMENTS, NUMERIC TESTS, AND INTER-CODE COMPARISONS RELEVANT TO THERMALHYDRAULIC CODE VALIDATION*

SE1 ↓	Edwards Pipe Blowdown	2 tests
SE25	WL Waterhammer Tests	about 48 tests
CO1 ↓	Stern Labs End Fitting Characterization Tests	about 600 tests
CO5	MR-2 Air-Water Test Loop	about 255 tests
INT1 ↓	Stern Pressure-Tube Burst Tests (IBT Series)	6 tests
INT7	RD-14M Shutdown Cooling Tests	9 tests
NUM1 ↓	JUICE Standard Problems	3
NUM10	Tank Bottom Discharge Tests	1
No Inter-Code Comparisons Identified at this Stage		

in one place information that has been generated over many decades and is dispersed in many references. These documents are useful now and are expected to make it easier to develop the validation matrix reports in the physics area.

3.7 Moderator and Related Thermalhydraulics

A Working Group has been formed to address moderator and related thermalhydraulics, and the Group has identified its scope of work. To date, the following tasks have been completed. A preliminary list of accidents involving the systems has been prepared. A preliminary list of concerns, behaviours, and phenomena for each accident has been developed. A preliminary table relating the major phenomena to accident has been prepared. Results of the above are being circulated for comment.

4. Future Validation Work

The methodology described in the preceding sections defines the course of action adopted by the Canadian CANDU industry to achieve the end point, which is computer codes, validated according to a structured methodology, and suitable for future safety analyses of CANDU plants and licensing decisions. That end point will bring to closure some of the code-development work and R&D, which in some instances has been ongoing for decades. The end products of the generic work presently under way will be a Technical Basis Document and six Validation Matrix Reports, the first of which has been completed and commented upon by staff from the Atomic Energy Control Board. These documents will provide the basis for planning the next steps in the validation program. In the next steps, the most appropriate computer codes will be selected and, if needed, validation plans for them will be defined. Any further code development will be focused on identified shortcomings. If gaps exist in the validation data base that can be addressed by additional R&D, such R&D will be specified and executed.

5. Nuclear Systems Other Than CANDU Plants

The preceding sections address the needs, with respect to validated computer codes, of the operators, designers, builders, and regulators of CANDU plants. AECL also operates other nuclear facilities, notably research reactors, and AECL designs, submits for licensing, and builds small reactors of the MAPLE family. The computer codes used in much of that work are often versions of those used in the CANDU business and hence require similar levels of quality assurance, including validation. The validation program described here provides a solid foundation to which specific validation work can be added to meet AECL's needs in the non-CANDU line of business. To foster close interactions between the CANDU and non-CANDU validation activities, a Working Group on Small Reactors has been formed within the scope of the Validation Team.

6. Summary and Conclusions

The Canadian CANDU industry has 35 years of experience in the development and application of computer codes used in safety analyses and licensing submissions. While these computer codes were validated as a matter of course during their development, that validation was performed according to the practice of the day. No single, systematic validation methodology was used because none existed. Recently, the OECD/NEA developed and published a validation matrix for system thermalhydraulics in LWRs, comprising two cross-reference tables: the first identifying physical phenomena that might occur in design-basis accidents, and the second identifying experimental and numerical tests that exhibit the physical phenomena. The validation matrix is generic to the chosen type of nuclear plant and serves as the basis for the validation of specific computer codes.

The Canadian CANDU industry adopted the fundamentals of the validation-matrix methodology for LWRs and is adapting and extending it to CANDU power plants. Industry-wide

TABLE 5: *EXCERPT OF THERMALHYDRAULIC PHENOMENA AND RELEVANT TEST DATA FOR CODE VALIDATION: Separate Effects Tests*

ID NO.	PHENOMENA	SE1 →	SE4 →	SE16 →	SE22 →	SE25
TH1 ↓	Break discharge characteristics & critical flow					
TH12 ↓	Quench/Rewet characteristics	∞	∞			
TH20 ↓	Waterhammer				∞	
TH23 ↓	Noncondensible gas effect					
∞ Suitable for direct validation ← Suitable for indirect validation						

Working Groups have been formed to develop validation matrices in six scientific disciplines:

i) System Thermalhydraulics;
ii) Fuel and Fuel Channel Thermal-mechanical Behaviour;
iii) Fission Product Release and Transport;
iv) Containment Behaviour;
v) Physics (comprising reactor physics, shielding, and atmospheric dispersion); and
vi) Moderator and Related Thermalhydraulics.

These disciplines cover a much broader range of phenomena than those addressed by the OECD/NEA.

The Working Group in System Thermalhydraulics has the lead and has produced a validation matrix document. Working Groups in the other disciplines are at various stages in developing their validation matrices which will be generic in each discipline. The validation program is expected to span several years and to bring to closure the development of computer codes, validated according to a structured methodology, and suitable for safety analyses of, and licensing decisions on CANDU power plants. While this is the primary focus for the work currently under way, the methodology and results will also provide a basis for the validation of computer codes used in safety analyses of nuclear and experimental facilities other than CANDU power plants, notably small reactors of the MAPLE family.

7. Acknowledgement

The authors acknowledge the work performed by the specialists at OHN, HQ, NBP, and AECL, too numerous to cite individually, and the members of the Validation Team, all of whom devote their energies and time to this joint program. Since the Working Group in System Thermalhydraulics has completed its validation matrix report, portions of which are quoted in this paper, the work of the authors J.M. Pascoe, A. Tahir, J.P. Mallory, and T.V.

Tran is hereby gratefully acknowledged.

8. References

[1] OECD/NEA, "Separate Effects Test Matrix for Thermal-Hydraulic Code Validation, Volume I, Phenomena Characterisations and Selection of Facilities and Tests; Volume II, Facility and Experiment Characteristics", Report OECD/GD(94)82, also NEA/CNSI/R(93)14/Part.1/Rev., Paris (1993).

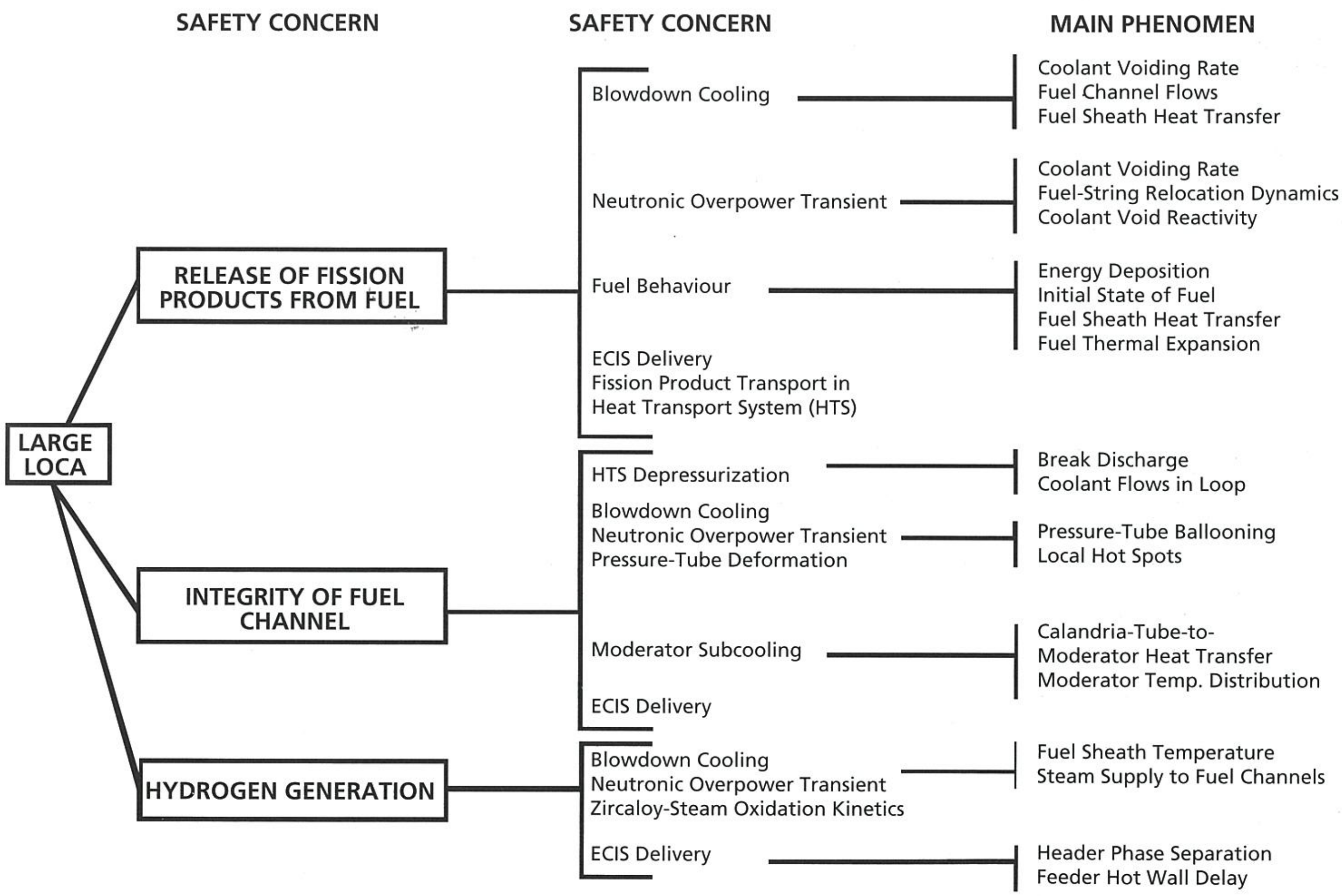


FIGURE 1: *TECHNICAL BASIS FOR LARGE LOCA*

More on Chernobyl

Root cause as identified by AECL analysts

***Ed Note:** The following explanation of the Chernobyl accident of April 26, 1986 is extracted from a paper presented by Dr. Jerry Cuttler, CNS president, to a special symposium on "Chernobyl, the Legacy", held at the University of Toronto, April 27, 1996. The symposium was organized by members of the Chernobyl Project, Faculty of Medicine of the U of T.*

What caused the Chernobyl accident? The Soviet authorities blamed the operators. The staff performed heroically, but three of them were sent to prison. The root cause was actually an error in the design of the neutron absorber rods that control the RBMK reactor.

As shown in Figure 1, each rod has a graphite section below the absorber section. With the original design, a rod was fully withdrawn it left a one metre space at the bottom which filled with cooling water. Water is a neutron absorber, so when the rods were dropped to shut down the reactor, the graphite, a neutron moderator, displaced this water absorber and added reactivity at the bottom of the reactor.

The operators in Chernobyl Unit 4 were trying to satisfy everyone. They wanted to help the safety analysts demonstrate that the spinning turbine-generator could power the cooling pumps for 30 seconds during a postulated loss of outside electricity, until the diesel generators started supplying electricity to the pumps.

They also wanted to help the electrical system administrator, who asked them to continue supplying power at 50% of output capacity to the public for another 9 hours. So, instead of following the approved test procedure – to reduce power to 50% and then trip the turbine, etc – they remained at 50% power and kept withdrawing control rods to compensate for collapse of boiling, moderator cool-down and build-up of fission products (xenon) in the fuel.

After the 9 hour delay, most of the 211 control rods were fully withdrawn, and the reactor was in a very unstable state. Instead of the neutron flux distribution being in the normal convex shape, it had a double camel-hump shape, as shown in Figure 2. The top of the reactor was becoming decoupled from the bottom of the reactor. The reactor became difficult to control. Power dropped from 50 to 7% of full power, and the operators tried to bring it back up by raising more rods. There were only 6 to 8 equivalent rods left in the core, when they finally dropped the rods to shut the reactor down.

The falling rods started to remove reactivity at the tops, but added reactivity at the bottom, when the graphite sections replaced the water. The rods went fully in within 20 seconds, but reactor power rose from 7% to 100 times full power within a few seconds as shown in Figure 3, and the reactor was destroyed.

There would not have been a power pulse if the graphite part had not been raised that extra metre. (The positive void coefficient was only a contributing cause – not the root cause as many people claim it was.)

The RBMK designers did not expect this operational sequence to occur. They blamed the operators for causing the transient, but there was no procedure that disallowed this sequence. The design was not forgiving of reasonable operator variance.

AECL analysts were the first to identify the root cause, and they performed the analysis[1] that explained the event. As shown in Figure 1, the corrective action taken by the Soviets was to lengthen the steel tie-rod to eliminate the space under the graphite.

1 "The Chernobyl accident: multi-dimensional simulations to identify the role of design and operational features of the RBMK-1000" P.S.W. Chan, A.R. Dastur, S.D. Grant, J.M. Hopwood, AECL-9426 1987.

	Length (m) new	Length (m) original
absorber	6.20	6.77
tie-rod	2.39	1.44
graphite displacer	4.55	4.56

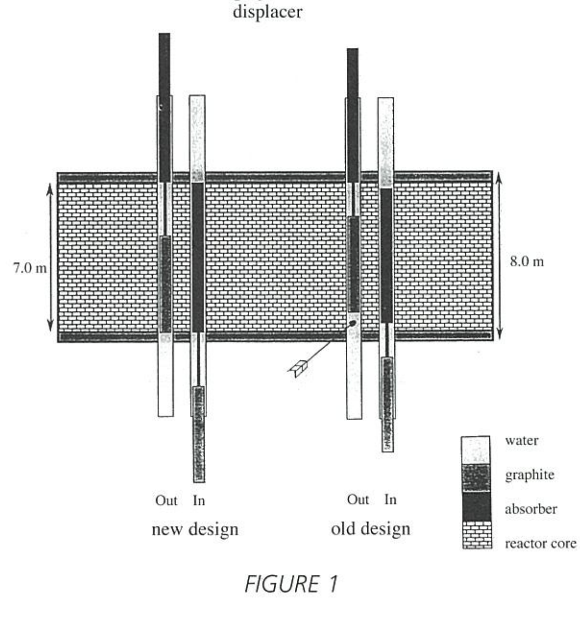
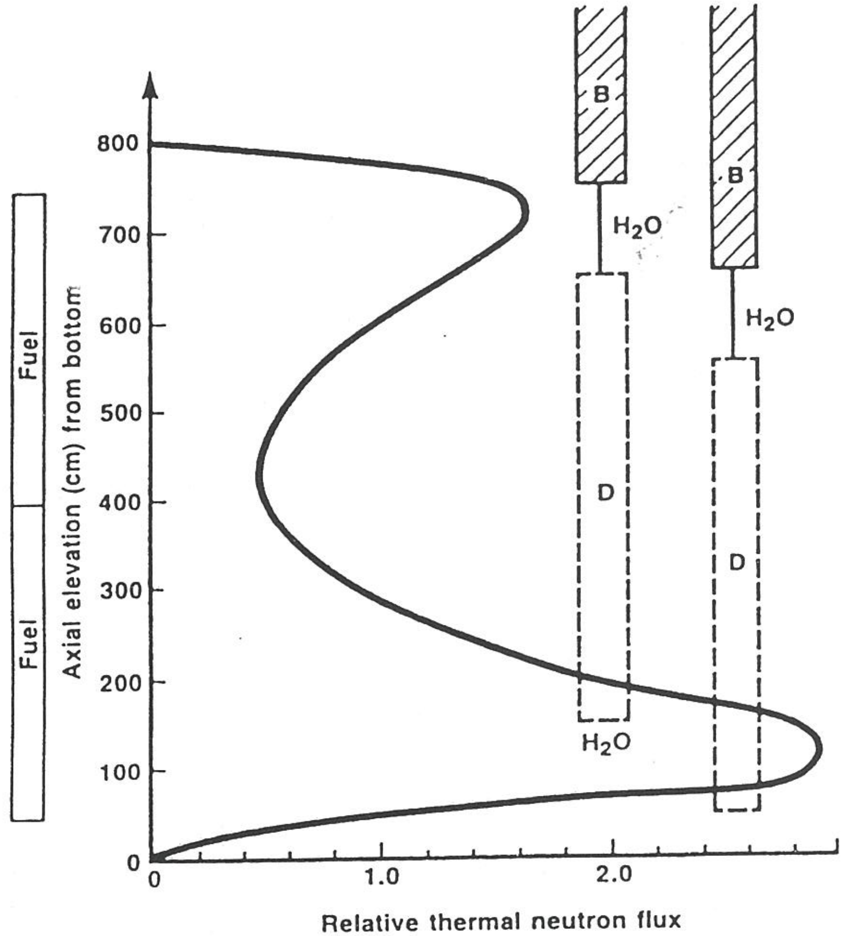


FIGURE 1



B = Boron carbide absorber
D = Graphite displacer

FIGURE 2. Neutron Flux Distribution Preceding the Power Pulse Transient

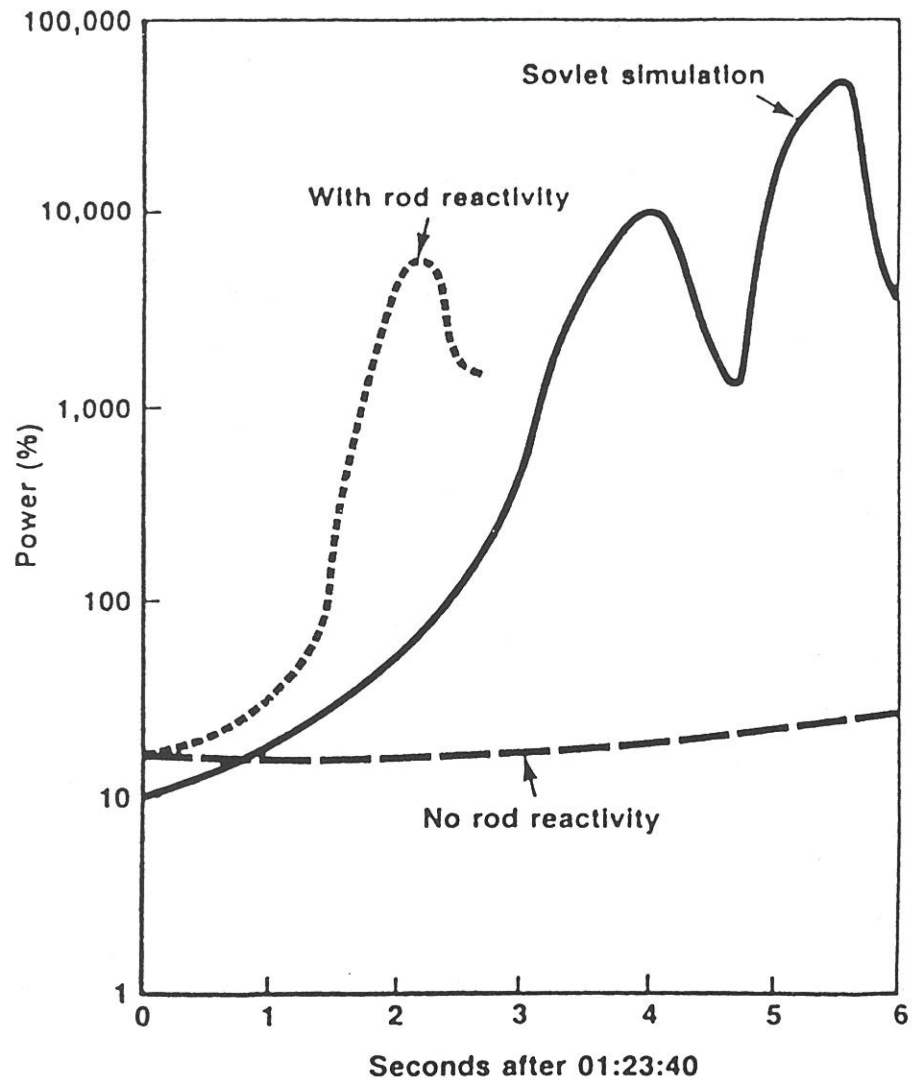


FIGURE 3. Effect of Control Rod Insertion on Reactor Power

GENERAL news

Cernavoda 1 Goes Critical

Ed. Note: *Our thanks to Sandra Vaughan of AECL Sheridan Park for the background information for the following note on Cernavoda.*

At 17:32 hours local time on Tuesday, 16 April 1996, the first unit of the five-unit Cernavoda nuclear power station in Romania was declared "critical". The start-up marks the first CANDU nuclear power unit in Europe.

Prime Minister Jean Chrétien who was visiting Romania at the time and Romanian president Ion Iliescu attended the official opening ceremonies held the following day.

The beginning of operation of Cernavoda is a major step in a long effort that began in 1979 when the then Communist government of Romania signed contracts with Atomic Energy of Canada Limited and the Ansaldo company of Italy. Under that agreement AECL would supply the nuclear plant design and Ansaldo the balance of plant. Although some specialized equipment was supplied from Canada, Romania was responsible for much of the manufacturing. Due to problems with the Romanian manufacturing, organization and financing, the project stalled.

When a new non-communist government took over in 1989 it declared Cernavoda to be a national priority. In 1990 AECL and Ansaldo formed the AAC Consortium and, in conjunction with the newly formed Romanian utility RENEL, reorganized and re-directed the Cernavoda project. Canada provided Romania with $315 million and Italy 175 billion lire in loans to fund the project. Since then the work has concentrated on completing Unit 1.

The consortium is responsible for Unit 1 operation for the first 18 months after commissioning. A hundred Romanian operations personnel have come to Canada for study and were attached to the Point Lepreau nuclear station in New Brunswick. Romanian regulatory people have studied with the Atomic Energy Control Board and there is an AECB representative resident in Romania.

Unit 1 is expected to reach full power in June.

Discussions are underway towards the completion of Unit 2.

New Nuclear Control Bill Introduced

In April, the Minister of Natural Resources, Anne McLellan, introduced in the House of Commons, Bill C-23, the proposed new Nuclear Safety and Control Act. The Bill has passed second reading and is now in the committee review stage.

The new Act will rename the Atomic Energy Control Board (AECB) to be the Canadian Nuclear Safety Commission, which the AECB hopes will end the confusion, to many in the public, between it and Atomic Energy of Canada Limited (AECL).

The new Act will make several major changes:

- the powers of inspectors will be enhanced and the maximum penalty for infractions will be increased to $1 million;
- financial guarantees will be required to cover cost of decommissioning;
- the renamed Commission will have the power to order remedial action;
- there will be legal provisions for public hearings, review and appeal;
- the number of Commission members will be increased from five to seven;
- provides for arrangements with other federal or provincial agencies.

This new Act, which has been developed over a five year period, will replace the existing Atomic Energy Control Act that was passed in 1946 and has had only one major revision.

Fusion Safety Seminar

In March 1996, the Canadian Fusion Fuels Technology Project hosted an intense two-day seminar on the safety of fusion reactors in Toronto. Although the number of attendees was modest, as might be expected for this specialized meeting, the presentations and discussion were both detailed and extensive.

Topics covered: fusion materials; safety design for ITER (International Thermonuclear Experimental Reactor); hydrogen production by beryllium-steam reactions; fusion safety standards; tritium source term analysis; tritium handling systems. Each paper went into its topic deeply.

ITER is the next proposed large fusion device intended to demonstrate the practicality of producing electrical power from a magnetic confinement fusion machine. The huge cost has led to an international partnership of Europe, Japan, Russia, and the USA to build it. Canada is involved as an associate of the European Union.

A group has been working for about two years to convince the partners to site ITER in Canada, with the Ontario Hydro Bruce or Darlington plant areas being proposed. (See CNS Bulletin, Vol. 16, No. 1, spring 1995.)

More information on the fusion safety seminar or ITER can be obtained from CFFTP in Mississauga, Ontario.

Deep River Science Academy

The Deep River Science Academy is a nonprofit, private, co-educational school with campuses at Deep River, Ontario; Pinawa, Manitoba; and Kelowna, British Columbia. It is run by volunteer boards of directors at both national and campus levels, including distinguished scientists nd engineers. Each campus is staffed by qualified professional educators.

Every summer, for the past ten years, the Deep River Science Academy (DRSA) has introduced bright, capable high school students from across Canada to the real world of science and engineering. In 1996 the Academy is promoting a summer of Real Science, Real Research and Real Experience.

Students who are seriously into science can discover what scientific work is all about. They can spend the summer doing real scientific word in real research labs to make a real contribution to science and engineering at the leading edge. As well, they can expand their mind with tutorials, workshops and informal lectures by distinguished scientists and have fun with great people & exciting classic summer recreational activities.

For over six weeks, 80 students from across Canada are put into projects that are part of current research programs at some of Canada's leading laboratories. They actively participate in scientific research in biology, chemistry, physics, engineering and environmental science. The research experience is unique in Canada and possibly the world. In recent summers, students have worked on a wide variety of leading-edge projects, from genetic engineering to sub-atomic particle accelerators, and from robotics to environmental science.

In 1994, the Academy received an award from the Conference Board of Canada for "Excellence in Business Education Partnerships". In 1995, it received the "Prime Minister's Award for Teaching Excellence in Science, Technology and Mathematics". In 1996, it received the Manitoba Sustainable Development Award for "Excellence in Education".

Students spend the weekdays working in pairs, under the guidance of an undergraduate-level tutor, who is employed by the Academy as a research assistant at their lab. Their work is supervised by a laboratory staff researcher who is a professional scientist of engineer. Students live in residence under adult supervision for the entire six weeks. They eat together, enjoy varied recreational activities together and pursue common intellectual interests. These times foster lasting friendships among students. Coming from across Canada and from varied backgrounds, they all share a love of science. This summer could count towards their academic standing. Not only can it fast-track students toward their high-school diploma but it can strengthen their resumé. Imagine being able to say that you spent a summer doing research in one of Canada's top labs.

Students aged 15 to 18, who have competed at least one science course at or beyond Grade 10 level may apply for a campus and program. Generous financial and other support from government and industry sponsors covers nearly half the costs of each session. The $3,700 fee covers tuition, accommodations for six weeks, meals, recreational activities and transportation between campus facilities. Generous bursaries are available from the Academy Bursary Fund, for eligible applicants. Many students are also successful in obtaining bursary support from local sources once they have been accepted at the Academy. The Canadian Nuclear Society has contributed to the DRSA Bursary Fund.

There is an application fee of $50.00; it is refunded only if the applicant is not selected by the Academy. Application forms are available from science teachers and guidance councillors across Canada or by calling 1-800-760-DRSA.

Program Issued for Deep Geological Disposal Conference

The preliminary program has been issued for the *International Conference on Deep Geological Disposal of Radioactive Waste* to be held in Winnipeg this September. With papers representing over 300 authors from at least 19 different countires this will be, undoubtedly, a major international affair. The conference is sponsored by the CNS with co-sponsorship of seven other societies or organizations.

The conference runs from Monday evening, September 16, 1996, to Thursday, September 19, with an optional workshop on *Excavation Disturbed Zone* or a *technical tour* to the Whiteshell and Underground Research Laboratories on Friday, September 20.

It will feature 10 plenary papers from almost as many countries on the theme, *International Trends in Geological Disposal,* and four plenary papers on, *Confidence Building in Radioactive Waste Management.* There will be 76 technical papers presented orally and 39 in poster sessions. The technical presentation sessions will generally run in two parallel sessions. They deal with the full range of topics related to geological disposal from modelling to sitting.

For information contact: Ms. Shannon Worma, Conference Secretary, Geological Disposal Conference, c/o AECL Whiteshell, Pinawa, Manitoba. Tel: (204) 345-8625. Fax: (205) 345-8868; e-mail: WORONAS@WL.AECL.CA

Changes at AECB

In early May, 1996, Dr. Agnes Bishop, president of the Atomic Energy Control Board, announced a number of changes of senior personnel and a partial reorganization to be effective May 15.

Jim Harvie will replace Zig Domaratzki as Director General, Reactor Regulation.

Harvie's former position as Director General of Research and Safeguards will be eliminated. Domaratzki is expected to be appointed to a senior post at the International Atomic Energy Agency this summer.

Harvie was associated with reactor regulation from the time he joined the AECB in 1974 until 1990 progressing from Project Officer at Bruce "A" to Manage of Power Reactor Division "B". He was appointed Director General of the Research and Safeguards Directorate in 1990.

Pierre Marchildon is appointed Director General of the Secretariat, the new name for the position of Secretary General. John McManus has requested to step down from the post of Secretary General but will continue to work on a part-time basis within the Secretariat for an indeterminate period.

George Jack will replace Pierre Marchildon as Director General of Administration and his current post of Deputy Director General of Administration will be eliminated.

Dr. Harold Stocker will become Director of a new division, Research and Safeguards, which will combine the two previous divisions of, Research and Support, and of, Non-Proliferation, Safeguards and Security. The new division will report to the Director General of Adminstration.

The Training Centre will now report to the Director General of the Secretariat.

ECI Fault Shuts Down Pickering

At the time of writing (mid May) all eight units at the Pickering NGS were shutdown because of a faulty check valve in the emergency Coolant Injection System (ECIS).

During routine maintenance the third week of April it was discovered that one of the two check valves in the line from the ECI storage tank was not operating properly. Reportedly a position indicating pin jammed the valve disc.

The check valves are designed to prevent water flowing back into the storage tank after it was emptied following triggering of the ECI system (which would occur for a loss-of-coolant-accident). Failure of the valves to close would be, in effect, a breach of containment. Failure of the check valves to open fully would be seriously impair the operation of the ECIS.

There is one motorized isolation valve between the storage tank and the check valves. However, closure of that valve disables the ECIS which is required to be fully operational. Since the ECI system feeds all eight reactors all had to be shut down when the isolation valve was closed to repair the faulty check valve.

The management of Ontario Hydro Nuclear decided to implement "quality of work" initiatives to improve operating procedures and general plant conditions before bringing the units back on line. Ontario Hydro president Alan Kupcis appointed two members of OH's Technical Advisory Panel on Nuclear Safety, Jon Jennekens, former president of the AECB, and Roger McKenzie, former manager of Point Lepreau, to oversee the work leading up to and including the start-up of the units.

Start up was expected to begin in late May.

CNS news

BRANCH NEWS

Exploits of a Nuclear Submarine

***Ed Note:** The following is extracted from an account of the talk by Capt. Philip Klintworth, LISN (ret), to a meeting of the Bruce Branch by a reporter, Tracey Doerr, of the "Shoreline News" of Port Elgin. Capt. Klintworth gave similar talks at Sheridan Park and to the joint Darlington/Pickering dinner.*

Captain Philip Klintworth's experiences with the United States Navy have earned him many credits and a bit of a celebrity status as well.

The 17-year nuclear submarine commander and professor of naval science, is often asked to share his knowledge about the technicalities of naval engineering. Producers of the successful 1980s movie, *The Hunt for Red October*, also found his knowledge valuable in making their film realistic. He was hired as the technical consultant for that production.

Although his experience with the movie must have been exciting, it's the U.S. Navy's 1962 exercise in the Arctic Ocean that Klintworth speaks of with enthusiasm.

After hearing that the Soviet Union was experimenting with subs in the Arctic, the U.S. Navy decided it had better learn to operate in that environment in case they ever went to war there. Klintworth was the commanding officer of a nuclear submarine called the Tautog. It, along with another submarine, was sent on the exercise.

The subs spent 43 days underwater, putting on 31,000 miles. During that time, it surfaced only 10 times.

"How thin does the ice have to be before you can surface?" asked the commander. "Well, that depends on how important it is to you. You'll try anything if you're movitated enough."

Klintworth said the ice in the Arctic Ocean is about 10 feet thick, but it's not homogeneous. For every foot of ice on the surface, there's seven time that below.

Facing deep ice keels, one as deep as 170 feet, made maneuvering the sub difficult at times. Klintworth said they determined "hostile" ice by the number of thin spots encountered. The thinner ice, the better their chance of surfacing. Ice needs to be six feet thick or less to break through the surface.

When they would finally find a spot to break through, Klintworth said they had to loop the sub around and keep it idle under the thin ice. Water was then pumped out of the sub, causing it to rise.

"Then, one of two things happens. You break through, or you don't."

When the sub got jammed against the ice and didn't surface, Klintworth said they'd have to charge air from the sub to get it up.

"In the ship, it's like a vacuum and the crew doesn't like that."

"In 1958 they started taking subs in the ice. There's not a lot of information on people who have hit the ice, but there's a lot if information from skippers who have hit bottom," he joked.

Klintworth said, when given the choice, he'd rather take the risk of hitting the ice.

The exercise Klintworth was sent on proved to be historic as it was the first time two subs had ever surfaced together in the winter. It was the second time two subs had ever surfaced together period.

The historic event happened to be a little too close for Klintworth's comfort. The commander of the other sub thought the Tautog was the spot on his sonar that was further away. In fact, that spot was a chunk of ice; the Tautog was dead ahead.

***Ed Note:** Much of the following was compiled by Ben Rouben, CNS vice-president and chair of the Branch Affairs Committee.*

Bruce Branch

On March 5, the Branch presented a seminar by Juris Grava (Ontario Hydro). As the title, "ITER/MOX/Bruce Unit 2 Update", suggests, the talk dealt with different topics: the status of Bruce Unit 2, the Phase-2 study of plutonium (MOX) burning in Bruce reactors presently being carried out for the US DOE, and the perspective for ITER, the International Thermonuclear Experimental Reactor. The seminar elicited much interest in the attendance of 29 people.

On April 23, the Branch presented "Nuclear Submarine Operations in the Arctic", a talk by Philip Klintworth, Senior Engineering Consultant, Advent Engineering Services Inc., and former US Navy nuclear submarine Captain (see description of talk under First Annual Dinner Evening of the Darlington and Pickering Branches). This event attracted a large audience of 65.

The following Branch seminars are planned for May and June:

1996 May 7: "CANDU Chemistry - The First Thirty Years; How We Got To Where We Are; Current Challenges and Future Initiatives", by Dr. Bob Stepaniak and Dave Iley

1996 Jun. 4: "A Regulator's Perspective - Mission, Objectives, Challenges", by Ted Dunstan, AECB

Chalk River Branch

On May 7, Dr. Jim Beckett, Director, Fisheries Research Branch (Fisheries and Oceans Canada), spoke on the "Cod Crisis".

The Branch is planning its Annual General Meeting for October.

Darlington and Pickering Branches: First Annual Dinner Evening

On April 22, the Darlington and Pickering Branches jointly held their First Annual Dinner Evening, organized by Branch Chairs Rick Murphy and Marc Paiment and their Executive teams. The venue was Cullen Gardens in Whitby. The evening started with a cash bar and was followed by a Roast Beef Dinner. The event was a great success, with more than 60 attendees who all had an excellent time.

The special after-dinner guest was Captain Philip Klintworth, USN (Ret). The talk, entitled "Nuclear Submarine Operations in the Arctic", was illustrated with slides and described nuclear submarine operations under the Arctic ice pack. In particular, it recounted the 1982 Arctic expedition of USS Tautog and USS Aspro, including the first rendez-vous of two submarines at the North Pole in winter. Captain Klintworth was Commanding Officer of Tautog and the Officer in Tactical Command of the expedition. His talk was very captivating, and included numerous entertaining anecdotes*. A biography of Philip Klintworth follows.

Captain Philip Klintworth was born and grew up in Oak Park, Illinois. He graduated from the University of Michigan in 1962 with a degree in Electrical Engineering, and was commissioned in the U.S. Navy through the Naval Reserve Officer Training Corps (NROTC) program. Entering the submarine force, Captain Klintworth spent over 17 years at sea, serving in the diesel submarine USS Remora, the nuclear attack submarines USS Permit and USS Snook, and the ballistic missile submarine USS Sam Houston. He commanded the ballistic missile submarine USS Theodore Roosevelt and the nuclear attack submarine USS Tautog. His sea-going career includes nine major deployments and five Polaris missile deterrent patrols. Captain Klintworth commanded the U.S. Naval Submarine Base at San Diego. He also served on the staff of the Naval Reactors Facility in Idaho, as the fleet nuclear power representative at Puget Sound Naval Shipyard, and as Professor of Naval Science and Commanding Officer of the NROTC Unit at the University of Michigan. He retired from the Navy in 1991. Captain Klintworth is presently employed as a Senior Engineering Consultant at Advent Engineering Services, Inc., of Ann Arbor, Michigan. Advent is a multi-discipline specialty engineering firm that provides services to operating nuclear power facilities. He is active in the Michigan Section of the American Nuclear Society.

Darlington Branch

The CNS Darlington Branch has had a busy program this past winter and early spring.

On February 1st, the Branch presented a lunch time seminar by Rick Murphy, PhD, of AECL Chalk River entitled "Inspection of Boiler Tubes using Tomography". More than 40 people in attendance at the presentation learned that a new technique for inspection of boiler tubes is being developed.

On February 9th, nine CNS members toured the Ontario Hydro Clarkson Control Center in Mississauga. A presentation was given by Steve Cooper of the Control Center, covering topics such as the makeup of the Ontario grid, the effect of disturbances in one part on other parts, interconnections with other utilities, the roles of control center control room staff, and the changes as a result of the new Ontario Hydro corporate structure. In addition, participants could overlook the control room from the conference room and see the displays available. The tour was enjoyed by those in attendance.

In early March a newsletter was sent to all Branch members describing the program for the spring.

Eric Jelinski, Technical Supervisor at Darlington NGD presented a paper entitled "The Hydrogen Economy – Energy and Environmental Analysis", on March 20. The presentation looked at all energy sources and applications and showed how comparisons should be made taking all costs into account. The 35 people who attended asked many questions.

On April 22, the First Annual Dinner Meeting was held jointly by the Darlington and Pickering Branches (see note above).

April was rounded out with two events at Darlington on April 26. The CNS Council held its regular bi-monthly meeting at DNGD attended by 13 council members. This was organized by the Darlington Branch to give CNS members and the CNS executive the opportunity to meet each other. At lunch time, Jerry Cuttler spoke to a Darlington audience of more than 50 in recognition of the 10th anniversary of the Chernobyl accident. Following that, a very interesting presentation was made by Imatez Malek, Project Officer of the AECB about AECB staff expectations for maintenance at a nuclear plant.

The Darlington Branch has one more event planned for June 18, that being a lunch time presentation by Reid Morden, President AECL, entitled "The CANDU Business: Today's Reality, Tomorrow's Potential".

The Branch has contributed $100 as an Award for Excellence in Science to a worthy student to Port Hope High School.

The Branch executive will meet to plan next year's program. An invitation is extended to any members of the Darlington Branch to participate in the executive.

Golden Horseshoe Branch

The Branch held its Career Night on March 21. This event took place at Wentworth Lounge of Wentworth House. It was intended primarily as an informal information session for the undergraduate students in the Department of Engineering Physics at McMaster University. The following industry representatives participated:

DEADLINE

The deadline for the summer 1996 (Vol. 17, No. 3) issue of the *CNS Bulletin* will be August 9 for publication about the end of August.

David Chettle (Medical Physics, McMaster University),
Don Dautovich (OHT),
Mike Lee (CANATOM),
Frank Stern (STERN LABS),
Jeremy Whitlock (AECL-CR)

The presentations were geared towards future job prospects and relevant education areas. The speakers provided a brief description and overview of their company or organisation, its place in the nuclear industry in Canada, and the present and projected employment situation in both their company and the industry as a whole. The presentations were followed by a social mixer.

Planned Branch activities involve organizing an essay contest for local high schools. The schedule for this activity is geared towards the end of the present school term.

The Branch also continues to be the curator of the CNS homepage on the World Wide Web. This can be found at the address

"http://www.science.mcmaster.ca/cns/www/cns/cns.html".

Manitoba Branch

The Branch hosted a talk by Dr. Paul Unrau on March 12. Dr. Unrau, of the Radiation Biology and Health Physics Branch, Chalk River Laboratories, described his work on the "Genetic Aspects of Radiation Risks". Dr. Unrau also gave the presentation at the Winnipeg Health Sciences Centre on March 11. Dr. Unrau evidently interested the people in the city, because he was getting messages the next day (at WL) to call people in Winnipeg. Here is the abstract for Dr.Unrau's talk:

"The interaction of genetics and environment leads to cancer risk. We have examined some underlying assumptions in risk assessment and believe that more attention must be paid to genetic risk determinants in order to better understand the basis of ionizing radiation risk. In particular, we have investigated the role of biological factors in shaping the genetic risks of individuals. Because individuals are genetically unique, apportioning risk on essential assumptions contains significant uncertainties.

Progress in the Human Genome Project leads to the expectation that genetic risk determinants can be analyzed and their effects measured. It appears that risks measured at population levels by epidemiological means reflect genes segregating in the individuals who make up the populations. We expect that a synthesis of molecular biological and epidemiological information will be required to adequately describe radiation risks."

On April 10th the Branch presented a lunchtime seminar by Rhea Cohen, Director of Communications at AECL. The talk was entitled "Nuclear Communications - How to Increase Public Confidence". The following notes on the talk were provided by Branch Chair Morgan Brown:

"Ms. Cohen's presentation went well. She's quite a good speaker and, as my wife said, 'Ms. Cohen kept our attention'. She feels quite strongly (as do I) that we must communicate to the public, the press and the politicians, informing them of the facts and figures about nuclear technology. She attended a conference in Europe recently, sponsored by the ENS, on nuclear communications. Apparently, the continual emphasis the nuclear industry puts on 'it's safe' is not getting through. The question period following the talk was lively and eventually had to be cut off due to time constraint."

Activities which the Branch is contemplating:

- a seminar by a speaker from Manitoba Hydro on high-voltage DC lines or on the complex inter-grid connections with Saskatchewan, Ontario and the USA.
- the Branch Annual General Meeting for June - perhaps another wine & cheese event with a speaker.

New Brunswick Branch

After a long hiatus due to the intense activity required for Pt.Lepreau to achieve its restart following the boiler-cover incident, the Branch has recovered and has resumed its seminar series.

On April 3, Stu Groom of New Brunswick Power gave a talk at the University of New Brunswick in Fredericton. The talk was entitled "Consequences of Foreign Materials Being Left in the Primary Heat Transport System in Pt.Lepreau".

On April 23, the Branch presented a seminar in Saint John. Peter Ahearn, of New Brunswick Power, described SLAR Work Done During the 1995 Pt.Lepreau Outage.

The Branch is also planning a meeting on the subject of simulator-based licensing examinations.

Ottawa Branch

The Branch was instrumental in organizing the 21st Annual CNA/CNS Student Conference on 1996 March 15-16. A field trip to the Chalk River Laboratories was organized for Conference attendees on March 14.

The Branch held its Annual Dinner Meeting on March 15, in conjunction with the Student Conference. The special guest speaker was Mr. Jon H. Jennekens, former President of the Atomic Energy Control Board and currently Chairman of Ontario Hydro's Technical Advisory Panel on Nuclear Safety.

Pickering Branch

The First Annual Dinner Evening of the Pickering and Darlington Branches was held April 22. See the description above.

Québec Branch

Saskatchewan Branch

In April the Branch organized two seminars by Jerry Cuttler. They were held in the AECL Saskatoon Office:

"1994 Pickering Loss-of-Coolant Incident", lunchtime presentation, April 15.

"Chernobyl Disaster - 10 Years Later; What Really Happened", afternoon presentation, April 16.

Sheridan Park Branch

In February, Don Dautovich, Vice-President Ontario Hydro Isotope and Sustainable Technologies Division, gave a wonderful presentation at Sheridan Park entitled; "Canada as host to ITER - The Next Stage in Fusion Energy Development". The presentation was made on behalf of the ITER siting board.

ITER - the first fusion engineering test reactor - is the next stage in the world's fusion energy development program. the purpose of the project is to demonstrate the engineering feasibility of fusion energy. ITER is the final step before a power producing commercial prototype reactor can be developed.

Don Dautovich mentioned that hosting ITER would bring a wide range of benefits to Canada and Canadians. It would create up to 87,000 jobs, up to $8 billion foreign investment in Canada. The presentation was absorbing and highly informative.

On March 28 the Branch presented a seminar by Mr.Paul Thompson (New Brunswick Power) on the "Clean-up and Start-up Following the PLGS Boiler-Cover Incident". Ted Wessman of the Sheridan Park Branch Executive provided the following seminar summary:

"The outage incident started when a wooden cover, used to prevent debris from entering the Heat Transport System during the planned outage, got drawn into the system during start-up. The result was that the wooden cover was shredded in the pump bowl, the pump impeller shaft sheared off and wood-cover debris was scattered throughout the inlet header and feeders. The consequence was an extension to the extended maintenance outage for approximately three months, to recover the debris and assess plant condition and secure regulatory agreement to restart the reactor.

This presentation was very well delivered.. The attendance was very high, with standing room only. The talk and the description of events following the incident, starting with the set-up of a recovery team and implementation plan to systematically reconstruct the event, assess damage, and address safety and licensing concerns was very enthralling. All this had to be done against the pressure of a very costly extension to the planned maintenance outage.

There was a terrific video taken by a robotic device that helped to assess the damage and recover some of the debris. Trial Sheridan Park Engineering Laboratory channel backflushing tests were also shown.. This was a large team effort, and Paul Thompson felt it was important to show the overall effort, as many of the participants saw only a small part of the recovery operation. The co-operation with Ontario Hydro was also excellent, as Bruce supplied the robotic mechanism for taking the videos. These videos were very instrumental in convincing the affected parties of the severity of the incident and of the need to address all safety concerns in a very systematic way. The AECB was kept informed and were impressed with the thoroughness of the recovery operation and safety assessment. This helped to secure the AECB's approval for getting the station back into operation according to the recovery team's phased start-up plan.

New Brunswick Power staff are reviewing materials management procedures during system maintenance outages to minimize any possibility of contamination of the Heat Transport System affecting future outages."

On April 24, the Branch presented "Voyages on Nuclear-Powered Submarines", a talk by Philip Klintworth, Senior Engineering Consultant, Advent Engineering Services Inc., and former US Navy nuclear submarine Captain (see description of talk under First Annual Dinner Evening of the Darlington and Pickering Branches). This seminar attracted a standing-room-only audience of about 70.

On April 25, the Branch presented a noon-time seminar by Emélie Lamothe (Radiation Biology Branch, AECL Chalk River), who expounded on the Women in Nuclear (WIN) organization. The talk was entitled "WINning Acceptability for the Nuclear Option". Following is Emélie's abstract:

"In May 1992, the international organization Women in Nuclear (WIN) was founded in Helsinki. This group of women, working within the nuclear industry, whether in the technical areas or in communications, give their time to communicate with the general public, especially with women, on the nuclear debate. The key concept is to appeal to women, as well as men, using reason and emotion, not just facts, in the discussion about nuclear energy. This presentation will briefly review WIN's communication strategy and current and future efforts in Canada"

On April 30, the subject was "Revisiting Chernobyl", with presentations by A.Dastur and J.Cuttler (AECL) and V.Moiseenko (McMaster University).

On the Education front, the Branch has contributed two $100 cheques as prizes to the 1996 Peel Regional Science Fair.

Toronto Branch

The Branch presented a seminar by Kim Vicente (University of Toronto) on March 29. The topic was "Advanced Human-Machine Interface Design for Nuclear Power Plant Control Rooms". The event attracted an audience of about 30.

For a future activity, the Branch is trying to organize a seminar on radionuclides in the environment.

The Branch administers the CNS R.E.Jervis Award at the University of Toronto. The 1995 Award winner, recently selected, is Ms. Sophia Wang.

Annual General Meeting

The 17th Annual General meeting of the Canadian Nuclear Scoiety will take place on Monday, 10 June 1996, at 1700 hrs, in the Grand Ballroom D of the Sheraton Inn, Fredericton, New Brunswick, in conjunction with the CNA/CNS Annual Conference.

The agenda will include reports from the outgoing president (Dr. Jerry Cuttler), from the treasurer (Ken Smith) and from the chairpersons of Committees and Divisions.

The proposed slate of officers fro 1996-97, below, will be presented. If no further nominations have been received by that date those members of Council will be confirmed.

President	Hong Huynh
1st Vice-President (president-elect)	Ben Rouben
2nd Vice-President	Aslam Lone
Treasurer	Ken Smith
Secretary	Jim Platten
Past-President	Jerry Cuttler
Members-at-large	Emelie Lamothe
	Guy le Clair
	Raymond Leung
	Jeff Lafortune
	Jad Popovic
	Ed Price
	Andrew Lee
	John Saroudis
	Graham Parkinson
	Surinder Singh
	Judy Ryan

The chairpersons of divisions and the editor of the CNS Bulletin are ex-officio members of Council.

Nuclear Science and Engineering	Krish Krishnan
Nuclear Operations	Ernie Aikens / Martin Reid
Fuel Technologists	Al Lane
Waste Management and Environmental Affairs	Mitch Ohta / Judy Tamm
Design and Materials	Bill Knowles
CNS Bulletin	Fred Boyd

CNS Committee Offers Teachers' Workshop

Ed Note: *The following is a self-explanatory notice sent out by Aslam Lone, chair of the CNS Education and Communications Committee to school boards in the Toronto area. He and his committee are prepared to assist teachers in other areas and request CNS members to pass on this information to their local school and boards.*

During the Annual Science for Educators Seminars held at AECL's Chalk River Laboratories, science teachers indicated that teaching the *Advance Science and Technology Curriculum* poses a real challenge. Science teachers felt they lacked the necessary background training, or often resources since equipment and audiovisual support material were not readily available.

To help close this gap the Education and Communication Committee of CNS (CNS-ECC), in partnership with Curriculum Departments of school boards, is arranging hand-on workshops for science teachers.

One workshop will be on ionizing radiation to meet the requirements of grade 12 curriculum. It will consist of the following experiments to be conducted by teachers under the supervision of volunteer scientists:

1 alpha, beta and gamma-ray tracks in a cloud chamber
2 alpha, beta and gamma-ray attenuation in various materials
3 half-life of radionuclide137Ba
4 application of alpha radiation in a smoke detector

To address the material needs for classroom demonstration, CNS-ECC will provide equipment from its resources. The following equipment will be avialable on a loan basis, free of charge, to participating teachers for experiments in their classrooms:

> Cloud chambers, flashlights, uranium rock and other radiation sources, alpha, beta and gamma radiation Geiger detectors, 137Ba radioisotope generator, smoke detectors, videos and fact sheets on properties and applications of ionizing radiation.

Teachers will be expected to provide dry ice and alcohol for cloud chambers and an IBM-compatible computer for data acquisition from the Geiger detector.

Please contact Dr. Aslam Lone, Chairman CNS-ECC for further information: Phone: (613) 584-3311; Ext. 4007; Fax (613) 584-1849; E-mail: Lonea@crl.aecl.ca

NEWS OF MEMBERS

Talbot Transferred

Ken Talbot, one-time president of the Canadian Nuclear Society, has been transferred from Director of Bruce "A" NGS to Director, Pickering Nuclear Power Division of Ontario Hydro Nuclear.

Also involved in the recently announced moves are Pierre Charlebois, currently Director at Pickering, who is moving to become Director, Nuclear Safety and Jim Bagshaw currently Operations Manager at Bruce "A" who will become Acting Director, Bruce "A". The appointments are effective June 1, 1996.

CNS Financial Statements for 1995

Ed. Note: *Although the term of office of the Council and Executive of the Canadian Nuclear Society runs from AGM to AGM (usually in June) the fiscal year is the calendar year.*

Auditors' Report

To The Members of the
Canadian Nuclear Society

We have audited the balance sheet of the Canadian Nuclear Society as at December 31, 1995 and the statements of operations and surplus for the year then ended. These financial statements are the responsibility of the Society's Council. Our responsibility is to express an opinion on these financial statements based on our audit.

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

In our opinion, these financial statements present fairly, in all material respects, the financial position of the Society as at December 31, 1995 and the results of its operations and changes in its financial position for the year then ended in accordance with generally accepted accounting principles.

Doane Raymond
Chartered Accounts
Toronto, Canada
March 18, 1996

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Canadian Nuclear Society
Statement of Operations

Year Ended December 31	1995	1994
Income		
Membership fees	$ 38,017	$ 36,327
Publications	4,503	5,208
Interest	10,233	8,350
	52,753	49,885
Society projects – excess of income over expenditures		
Annual conference	14,522	28,387
1994 Containment conference	(2,245)	30,408
1994 Steam generator conference	(318)	22,178
1994 Reactor Safety Course	78	10,454
1994 Chemistry course	–	2,989
Simulation Symposium	7,973	13,804
Environmental Assessment – Disposal Concept	597	–
1995 CANDU Maintenance Conference	71,161	–
1995 CANDU Fuel Conference	8,551	–
1995 Reactor physics course	7,670	–
	107,989	108,220
Total income	160,742	158,105
Expenses		
Net expenditures by branches	15,832	16,316
Committees		
Membership	8,468	11,507
Program	1,044	4,408
Fusion	29	95
Awards	2,256	998
Education and public affairs	1,219	8,784
Women in Nuclear	95	–
Inter-society relations	993	700
	14,104	25,792
Office support	50,000	48,000
Office services		
Audit fees	2,500	2,500
CNS Council expenses	2,182	1,631
Stationery and office supplies	4,856	5,586
Bank charges	291	457
Credit card charges	152	1,151
Computer programming	1,152	1,180
Telephone	1,367	1,428
Casual labour	–	615
Insurance	1,188	1,080
Postage	12,883	16,356
Printing and copying	5,697	2,400
Courier charges	280	517
	32,548	34,901
Canadian Nuclear Society Bulletin	22,737	20,698
Special Projects		
Student conference	1,365	1,403
Proceedings and promotional supplies	3,717	8,624
Officer's seminar	3,514	4,185
ZEEP - 50th anniversary	1,515	–
	10,111	14,912
Total Expenses	145,332	160,619
Excess of income over expenses	15,410	(2,514)
Members Equity, beginning of period	205,768	208,282
Excess of income over expenses	15,410	(2,514)
Members Equity, end of period	221,178	205,768

Canadian Nuclear Society
Statement of Operations

Year Ended December 31	1995	1994
Assets		
Current		
Cash		
Bank accounts	$ 173,874	$ 75,601
Nuclear Operations Division	1,823	–
Branch bank balances	16,812	13,296
Receivables	25,015	33,548
GST receivable	–	1,725
Accrued interest	500	874
Prepaids	–	24
Marketable securities (market value - $49,919; 1994 - $85,347)	52,188	91,318
Conference advances	8,000	6,500
Due from Canadian Nuclear Association	8,737	–
	286,949	222,886
CNS share of Education Fund assets (Note 2)	17,000	17,000
	$ 303,949	$ 239,886
Liabilities		
Current		
Payables and accruals	$ 54,543	$ 2,516
GST payable	2,046	–
1996 membership fees received in advance	9,182	6,121
Due to Education Fund	–	300
Due to Canadian Nuclear Association	–	8,181
	65,771	17,118
Members Equity		
Accumulated surplus	221,178	205,768
Education Fund (Note 2)	17,000	17,000
	238,178	222,768
	$ 303,949	$ 239,886

On behalf of the Canadian Nuclear Society Council

Canadian Nuclear Society
Statement of Operations
Year Ended December 31

1. Summary of Significant accounting policies
   (a) Revenue recognition
   Membership fees are included in income in the fiscal year to which they relate.
   Interest and other income is recorded on the accrual basis.
   (b) Marketable securities
   Marketable securities are carried at cost adjusted for amortization of premiums or discounts.

2. Education Fund
   From 1988 to 1991, annual contributions amounting to $3,000 from the Society and $7,000 from the Canadian Nuclear Association (CNA) were allocated from the income from the annual conference. In 1994, the Society made an additional contribution of $5,000. The principal remains the property of the CNA and the Society. The interest on these funds is available for education purposes to local branches of the society.

	1995	1994
The total fund is composed as follows:		
Principal contributions		
Canadian Nuclear Association	$ 28,000	$ 28,000
Canadian Nuclear Society	17,000	17,000
	45,000	45,000
Accumulated interest available to Canadian Nuclear Society local branches	7,500	9,387
	$ 52,500	$ 54,387

1996

June 9 - 12
CNA/CNS Annual Conference
Fredericton, NB
contact: Sylvie Carson
CNA/CNS office
Toronto, ON
Tel: 416-977-6152 ext. 18
Fax: 416-979-8356

June 9 - 12
Canadian Radiation Protection Association Annual Meeting
Tjrois Rivières, PQ
contact: Michel Rhéaume
Centrale Nuclieare Gentilly
Gentilly, PQ
Tel: 819-298-5252
Fax: 819-298-5039

June 9 - 12
TOPSEAL '96, Demonstrating the Practical Achievements of Nuclear Waste Management and Disposal
Stockholm, Sweden
contact: TOPSEAL '96 Secretariat
European Nuclear Society
Tel: 41-31-320-6111
Fax: 41-31-382-4466

June 16 - 20
ANS Annual Meeting
Reno, Nevada
contact: ANS
La Grauge Park, Illinois
Tel: 708-579-8258
Fax: 708-352-0499

July 21 - 26
ASME Pressure Vessel Conference
Montreal, PQ
contact: Dr. R.C. Gwaltney
Oak Ridge National Lab.
Oak Ridge, TN
Tel: 615-574-0740
e-mail: rcg@ornl.gov

August 18 - 24
SPECTRUM '96 – ANS International Topical Meeting on Nuclear and Hazardous Waste Management
Seattle, WA
contact: K.L. Skelly
Richland, WA
Tel: 509-376-3931
Fax: 509-372-3777

September 8 - 11
5th International Conference on Simulation Methods in Nuclear Engineering
Montréal, Québec
contact: J. Saroudis
AECL Montreal
Tel: 514-871-1116
Fax: 514-934-1322

September 16 - 19
Deep Geologic Disposal of Radioactive Waste
Winnipeg, MB
contact: M.M. Ohta
WL Pinawa, Man.
Tel: 204-345-8625 ext. 201
Fax: 204-345-8868
e-mail: ohta@wl.aecl.ca

September 17 - 20
IAEA Specialists Meeting on Experinece and Improvements in Advanced Alarm Annunciation Systems
Chalk River, ON
contact: L.R. Lupton
AECL - CRL
Tel. 613-584-8811 ext. 3433
Fax 613-584-9541
e-mail: luptonl@crl.aecl.ca

September 29 - October 2
Canadian Society for Chemical Engineering Annual Conference
Kingston, ON
contact: Dr. H.W. Bonin
RMC
Kingston, ON
Tel: 613-541-6613
Fax: 613-542-9489

September 30 - October 2
Economic Nuclear Power for the 21st Century
Paris, France
contact: TOPNUX '96
Société Frkancois D'Energie Nucléaire
Tel: 33.1.44.19.62.16
Fax: 33.1.44.19.62.22

October 7 - 9
Yugoslav Nuclear Society Conference
Belgrade, Yugoslavia
contact: Radojko Pavlovic
Belgrade
Fax: ++ 381-11-455943

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October 14 - 18 **International Symposium on Nuclear Energy and the Environment**
Beijing, China
contact: Chinese Nuclear Society
P.O. Box 2125
100822, Beijing, China

October 20 - 25 **10th Pacific Basin Nuclear Conference**
Kobe, Japan
contact: 10-PBNC
Atomic Energy Society of Japan
Tokyo, Japan
Fax: 81-3-3581-6128

October 27 - 31 **General Conference on Nuclear Energy**
Rio de Janeiro, Brazil
contact: Everton de Almeida Carvalho
Brazil Nuclear Energy Assoc.
Fax: 55-21-541-8785

November 10 - 15 **ANS/ENS International Meeting**
Washington, DC
contact: ANS
Le Grange Park, Illinois
Tel: 708-579-8258
Fax: 708-352-0499

November 17 - 22 **ASME International Mechanical Engineering Congress**
Atlanta, Georgia
• Symposium on Inelastic Methods for Structural Analysis and Design
contact: Robert Sammataro
Electric Boat Div.,
General Dynamics
Groton, Conn.
Tel: 860-433-3904
Fax: 860-433-3157
• Session on Exp:l Study of Multiphase Flow
contact: Dr. B.W. Yang
Columbia University
New York, NY
Tel: 212-280-4163
Fax: 292-678-5279

1997

March 23 - 26 **Advances in Fuel Management**
Myrtle Beach, SC
contact: Dr. Paul Turinsky
North Carolina State Univ.
Rawleigh, NC
Fax: 915-515-5115
e-mail: turinsky@eos.ncsu.edu

April 6 - 11 **4th International Conference on Methods and Allications of Radioanalytical Chemistry**
Kailua-Kona, Hawaii
contact: Sylvie Carson
CNS office
Toronto, ON
Tel: 416-977-7260 ext. 18
Fax: 416-979-8356

April 14 - 18 **5th International Topical Meeting on Advanced Reactors Safety**
Beijing, China
contact: Ken Talbot
Bruce NGD 'A'
Tiverton, ON
Tel: 519-361-2673

May 13 - 16 **CRPA Annual Conference**
Victoria, BC
contact: Sylvie Carson
CNS office
Toronto, ON
Tel: 416-977-7260 ext. 18
Fax: 416-979-8356

June 1 - 4 **2nd International Topical Meeting on Advanced Reactors Safety**
Orlando, Florida
contact: Dr. Rusi Taleyarkhan
Oak Ridge National Lab.
Oak Ridge, TN
Tel: 423-576-4735
Fax: 423-574-0740
e-mail:
zrt@cosmaill.ornl.gov

June 8 - 11 **CNA/CNS Annual Conference**
Toronto, ON
contact: Sylvie Carson
CNA/CNS
Toronto, ON
Tel: 416-977-6152 ext. 18
Fax: 416-979-8356

August 17 - 21 **International Conference on Neutron Scattering**
Toronto, ON
contact: Dr. W.B.L. Buyers
AECL Chalk River Lab.
Chalk River, ON
Tel: 613-584-3311
Fax 613-584-1849

September ? ? **5th International CANDU Fuel Conference**
Toronto, ON
contact: Dr. J. Lan
AECL - SP
Tel: 905-823-9040

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1997 *continued*

September 30 - October 4

NURETH-8, 8th International Topical meeting on Nuclear Reactor Thermal Hydraulics
Kyoto, Japan
contact: Dr. Jerry Cuttler
AECL - Sh. Pk.
Mississauga, ON
Tel: 905-823-9060 ext. 2556
Fax: 905-855-0945

October 5 - 10

Global '97 International Conference on Future Nuclear Systems
Yokohama, Japan
contact: Dr. Jerry Cuttler
AECL - Sh. Pk.
Mississauga, ON
Tel: 905-823-9060 ext. 2556
Fax: 905-855-0945

October 6 - 10

International Conference on Mathematical Methods and Supercomputing for Nuclear Applications
Saratoga Springs, NY
contact: Dr. M.R. Mendelson
Tel: 518-395-7046

November ? ?

4th CANDU Maintenance Conference
Toronto, ON
contact: Sylvie Carson
CNA/CNS
Toronto, ON
Tel: 416-977-6152 ext. 18
Fax: 416-979-8356

1998

May 3

11th Pacific Basin Nuclear Conference
Banff, Alberta
contact: Ed Price
AECL Sheridan
Tel: 905-823-9040
Tel: 613-584-3311
Fax: 613-584-1849

BOOK Review

MY LIFE WITH RADIATION – The Truth About Hiroshima

Reviewed by Fred Boyd

by Ralph E. Lapp
Cogito Books, 1995

Ralph Lapp "fell" into the Manhattan project when, as a graduate student under Arthur Compton in 1942 at the University of Chicago, he inadvertently entered the Staff Field area where Fermi and company were constructing the first reactor. Compton then asked him to join the project.

He worked in radiation protection and recounts that because of security "radiation" could not be used so they coined the phrase "Health Physics" which is still in use today. The standard for external radiation at the time was 0.1 roentgen per day. He notes that after the bombs were dropped on Hiroshima and Nagasaki radiation was widely used and usually reported as "deadly radiation" and the adjective was stuck.

After obtaining his Ph.D. in 1946 Lapp continued with the bomb program for the tests at the Bikini Atoll in the South Pacific. The following year he joined the staff of Vannevar Bush, science adviser to the Pentagon and started writing, initially training manuals on radiation safety. In 1949 he decided to become a full-time writer specializing in nuclear matters.

From that perspective he recounts the development of the H bomb, bomb tests, fallout and then goes into the major thrust of the book with chapters on, "How Deadly is Radiation?", "Radiation, Politics and Legal Battles", Radiation controversies, "Low-level Risk". He is critical of the extension of the Japanese data to doses below 20 rem and of the entire linear, no-threashold theory of radiation effect.

His last sentence summarizes his feelings and probably echoes that of many. "The public perception of radiation risk is so distorted that it will take many years for an informed public understanding of radiation risk issues."

Interesting additions to the book are the Prologue which gives an account of how Leo Szilard and Eugene Wigner convicned Albert Einstein in 1939 to write the letter to US President Roosevelt that led to the Manhattan Project and the Epilogue which contains a letter by Szilard and others to President Truman in July 1946 urging him not to use the bomb aginst the Japanese.

This book should appeal to those interested in another account of the history of the US nuclear program and to those who share Lapp's dislike of the linear, no-threshold hypothesis.

THE DARKER SIDE

by George Bauer

Hands up those who have heard of Joe Bailey. (Why do we always see the same hands?)

For those of you who were honest and didn't put up your hands, allow me to admit that I hadn't heard of Joe Bailey myself until a few days ago. Now old Joe was a real benefactor to the race. He was (maybe still is) a professor at the University of Texas who specialised in the half lives of panaceas. In particular, he concentrated on educational and business panaceas, and he had worked out that their half life was seven years (plus or minus about two years). We can all agree that the precision could be improved, but Joe was spot on as far as topic goes. He was not, incidentally, the first to be concerned with cyclic behaviour in social matters. Arnold Toynbee spent years on a cyclic theory of history and wrote some twenty volumes of the stuff only to be crapped on by his peers, unfelicitous though that last bit may sound. More recently, Cesare Marchetti claimed to have shown that societies have a natural time constant of about 54 years. Must be something in the water. When one comes to consider it, the notion of something going through cycles is not new at all. They are everywhere, in fact. There are cycles in religion, in business and in the weather. There is a hydrologic cycle, a solar activity cycle, and fashion cycles. One can find tidal, diurnal, circadian, planetary and computer cycles. There are even regulatory cycles, although they seem to go backwards. About the only thing that doesn't go through cycles is a cyclist.

But Joe wasn't just into any old cyclic lark. His real interest was in the oldest activity in the world: bluffing. Note that bluffing isn't a profession. Not like, say, farming, or even older ones.

Joe was a pioneer in this area. His work has been greatly extended by synthetic masterpieces like "The Bluffer's Guide to Bluffing". In fact, it may be one of the most important books you never bought.

But back to the process. It happens like this. Somebody writes something original and has it published. Somebody else reads it and his eyes fill with images of brownie points, so he uses bits of it. Soon a following gathers. Before you can say "Merde alors!", hordes of spin doctors are at work on the thing and it becomes restructured beyond recognition. It becomes post-restructured. Eventually, all this blathering and verbal reprocessing becomes cyclic. Nobody remembers where the beginning was any longer and thing acquires a life of its own. In very short order, so much will have been written, discussed, orated, brayed, preached, chattered, blustered, pronounced, addressed, reviewed, critiqued, rebuffed, contradicted, emphasised, conferenced, refuted, trashed, rhubarbed, shambolicated and, well, just "said", that it passes into public life. Everybody starts uttering sentences that have bits and pieces of this rubbish spliced into them, verbal symptoms of a more serious underlying mimetic psychosis. (As an example, most of us have been horrified to see a long-standing and trusted friend suddenly, and without warning, be overcome by a vacant and unwelcome grin. While it spreads across his or her face, the mouth works puppet-like and the eyes focus inward on some personal satanic emptiness, and then they croak out the phrase "You deserve a break today". It's ghastly. You have to slap them and throw ketchup in their face to drive out the Scottish demon and recover your friend.) This reflects the late stages of the pathology. A good example of something that is at the back end of this cycle is TQM. Everybody knows about it, on a hearsay basis. It's a fashionable topic for appropriate occasions.

Now the point is that there are generally many things that are in this late cyclic stage. The greenhouse effect, the deficit, nuclear safety, cholesterol, the return of the outhouse. (Actually, I just invented that last one.) If any of these topics comes up in conversation, you can't just sit there and say nothing. You have to have an opinion, preferably one that's rock-hard. But it's not possible to be even slightly knowledgeable on all of them. The answer: bluffing. Social survival today requires that you be able to shoot a good line, possibly on more than one level, without necessarily having the slightest idea what the hell you're talking about. Viewed in this light, it's easy to see that bluffing is, in the words of Ron Zemke, "a basic life skill". Back to TQM. How do I know that it's on the way out? Look at the walls of corporate offices across the country. The posters, diagrams and slogans have quietly vanished. (Are we moving back to old Deming's precepts? "Get rid of slogans, targets and buzzwords", and (my favourite) "Benchmarking is an activity engaged in during the last stages of civilised life".)

The message is clear. Listen to the topics being discussed around you. Were any of the people involved experts? No. Did all of them speak as though they were experts? Yes. So what are you waiting for? You don't have to go to extremes, though. There's no need, for instance, to cross the continent on a motorcycle, listening to the engine note and getting your teeth covered with bugs. Moving to Scarborough won't necessarily help, although it appears that the percentage of bluffers there is higher than elsewhere. You could put up lots of generic control charts in your office. If nothing else it will intimidate the boss and keep him out of your way. You could buy up old statistics books and range them prominently on your bookshelf. You could compile lists of big words and learn nice sounding sequences of them. The sheer drama of their presentation will convince people that they actually mean something.

How do I know all this? The long answer? Extended involvement in a QA programme. The short answer? Guess.

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