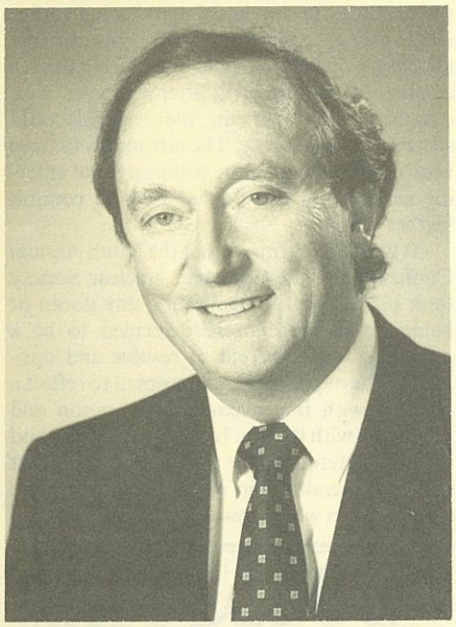
Canadian Nuclear Society Société Nucléaire Canadienne

CNS BULLETIN SNC

Vol. 9, No. 4 July / August / juillet / aout 1988

Message from the President



Ken Talbot

The traditional opening statement for this message goes something like this; "It is a pleasure and an honour to have been elected President of the Canadian Nuclear Society", or words to that effect. Indeed, after some thought, I realized I couldn't better that statement, and I'll tell you why.

There are several characteristics of our membership that make it a pleasure to serve. We are enthusiastic, we enjoy pursuing our endeavours, we are technically excellent and innovative and we are willing to take a few risks in pursuing excellence in the dissemination of our nuclear technology. The Journal was a recent example of an innovative venture which unfortunately failed, *not* due to membership effort but rather due to lack of external institutional support. Here lies the key to the direction I would like to see our Society move over this coming year.

Our strength lies in the technical competence and vitality of our members. The council's efforts will be directed, this year, towards increasing our membership and its involvement in both our Society and external society activities.

We will be producing a publication to make up for the loss of the Journal. This "enhanced" Bulletin should be coming out later this year. The Bulletin is your publication and is presently produced by a very few enthusiastic and august individuals who need your help with articles and other support. Please give Jatin Nathwani (416-592-6855) or Keith Weaver (416-592-6771) a call if you feel you can help.

People who belong to organizations such as ours are proud of their society and often like to demonstrate their affiliations with pins, ties etc. We will be attempting to produce something for you of this type, this year.

We are going to wave the Uranium Mining Flag with a new type of Conference: a fully international symposium on Uranium and Electricity to be held in Saskatoon in September. The program committee is also working on a full slate of events for the coming years. On the rest of the international scene we will be participating in events sponsored by other nuclear societies and will be attempting to develop cooperation agreements with them.

We will continue to develop the "Educate the Educators" program and will help, in whatever way we can, the public information program of the CNA. Recent polls indicate that the Nuclear Industry has "earned the right to speak" – well, so have the individuals within those industries and I would like to see us capitalize on that.

The branches and technical divisions are all well and we will be trying to stimulate more activity via council visits to branch locations and offers of speakers etc. These organizational units are the life blood of our society and it is through them and other institutes of learning, that we will be trying to stimulate more membership and interest in our society and technology.

The time is right for change, we have increased the size of council and with the 70% change in its membership, should enable us to tap into more volunteer time and energy. The council will be meeting once a month to build up momentum and we will be vigorously pursuing our programs while perhaps accepting some risks along the way. The individuals who started our technology, certainly took calculated risks in their venture with overwhelming success. I would like to see us follow suit so that when the question has to be answered as to what energy source to use for future generations to preserve the environment, the nuclear option is right there on top of the list.

This year's annual Conference at Winnipeg gave me a positive feeling towards the future. We have the fuel, we have the technology, we have the people and I am honoured to be able to help ensure we have the *will* to put nuclear technology where it belongs, right up front.

Ken Talbot

Contents

Editorials

Something in the Air

During four days at the end of June, a watershed conference was held in Toronto. The International Conference on the Changing Atmosphere heard a range of speakers who discussed what is happening to the atmosphere, how serious it is, what should be done about it and what some of the implications might be.

The conference statement did not mince words.

"Humanity is conducting an unintended, uncontrolled, globally pervasive experiment whose ultimate consequences could be second only to a global nuclear war. The earth's atmosphere is being changed at an unprecedented rate by pollutants resulting from human activities, inefficient and wasteful fossil fuel use and the effects of rapid population growth in many regions. These changes represent a major threat to international security and are already having harmful consequences over many parts of the globe."

In an age (and in an industry) where wrung hands and doom-filled projections are the order of the day, one may tend to shrug off yet another example of the genre. This one may well be different.

Globally-averaged temperatures have increased by 0.7 degrees over the past century, and a further increase of 1.5 to 4.5 degrees before the middle of the next century is consistent with the current and expected rates of release of greenhouse gases. At high latitudes, the warming experienced could be double the global average. These temperature increases, occurring over 100-200 years, exceed those that have taken place over the past 5000 years.

The effects of changes on this scale will not likely be pleasant.

Sea levels could be expected to increase by from 30 centimetres to 1.5 metres by mid-century. A warmer planet would mean a more "vigorous" climate with a more active hydrologic cycle. The nature and frequency of tropical storms could be altered, local rainfall and temperature patterns, with their implications for agriculture, could be affected, and the patterns of ocean currents could be changed. Climate changes and alterations in agriculture or food supplies would likely affect the poorer nations but in general it may have the effect of increasing the potential for conflict among nations. Perhaps most important is the uncertainty associated with the rate at which these changes may occur. The release of yet more greenhouse gases may commit the planet to a warming and a rate of warming which is fast enough that there would be little or no time to understand its mechanism and to reverse its causes.

The problem lies mostly with the developed countries, since it is they who have released the bulk of the offending gases, and partly with those developing countries which are removing rainforests relentlessly. The conference statement lists a number of actions to be embarked upon. First there is the inevitable international action plan, to be backed up by concerted national actions. The developed countries would be expected to bear the brunt of the load here, by improving the energy efficiency in those devices consuming fossil fuels, by switching to fuels or energy sources which emit less CO_2 or none at all, and by agreeing to halt the release of other greenhouse gases such as chlorofluorocarbons.

The targets suggested for reduction in CO_2 seem not unreasonable, at least until all the implications are considered. The conference report estimated that a reduction by more than half in the current rates of release of CO_2 would be necessary to stabilize climate warming. The target suggested for the year 2005 is a reduction by 20% of the present (1988) release rate. It is suggested that half of this reduction could be brought about by efficiency measures and half by a "modification" in fuel supplies. Essentially, this means that 20% less carbon would have to be burned in 2005 than will be burned this year, worldwide. Since the developing countries will likely have to increase their rate of hydrocarbon consumption (most can scarcely be expected to decrease it), the developed countries would have to throttle back their carbon and hydrocarbon consumption drastically. Goals such as these would require a complete rethinking of energy policies. In the recent past, the cry was 'Conserve Oil'; the next is likely to be 'Conserve Carbon'.

The big loser at this conference was coal. But a clear winner (for a change, some might say) was nuclear power. Thus one of the items falling under the heading "Recommended Immediate Action" was the following:

. . . revisiting the nuclear option, which lost credibility due to problems related to nuclear safety, radioactive wastes and proliferation. If these problems can be solved, through improved engineering designs and institutional arrangements, nuclear power could have a role to play in lowering CO_2 emissions."

The wording may seem rather timid, but it should be recalled that many of the people involved in this conference were probably, in the recent past, not exactly craving the appearance of more nuclear stations. Timid as it may seem, the statement is hardly short of revolutionary, coming from an environmental conference.

In summary, mankind appears to have manoeuvred itself into a bit of a corner. There are few ways out. Some of them are not particularly palatable; the rest are definitely unpalatable. A judicious application of nuclear energy is likely to figure among the former.

Some may take this development as a sign that happy days are here again, and that we should start gearing up to the old ascending growth curve once more. That would be unenlightened and wrong-headed.

Thinking of that sort, applied generally, was perhaps, in hindsight, one of the reasons we found ourselves in this corner at all. The way out of our problem is unlikely to be through application of the sort of policies which gave rise to the problem in the first place.

There is an opportunity here for the nuclear community, in Canada and elsewhere. It involves understanding thoroughly a complex situation, what our particular role in it might be, and proving to ourselves and to everyone else that our component of the solution is right, good, proper and necessary.

Let's not fumble it.

On the Skids?

The nuclear industry in Canada is on the skids. Or so one might be led to believe.

With the demand for electricity expected (a few years ago) to be soft or static for some time, with utilities (a few years ago) facing rather large excess capacities, with governments lukewarm or unfavourable, with hiring freezes as plentiful as toadstools after a shower, with costs and objections rising, the prognosis could scarcely be called rosy. The last plants to have been committed are now within sight of entering service and there is no rush to commit further plants.

It was in this climate that the Ninth Annual Conference of the Canadian Nuclear Society took place. Far from reflecting any doom or being on its uppers, there seemed to be a refreshing undercurrent of resolve and optimism. The papers generally seemed to reflect a concern with improvement, innovation and getting on with the job. Indeed, the quality and inherent interest of the papers was such that one could readily find participants who were torn between which session to attend next and

CNS BULLETIN SNC

ISSN 0714-7074

The CNS Bulletin is the membership publication of the Canadian Nuclear Society; 111 Elizabeth St., 11th Floor; Toronto, Ontario; Canada; M5G 1P7. (Telephone (416) 977-7620; Telex 06-23741; Fax 979-8356). Published every two months; deadline for contributions 1st of every odd-numbered month.

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 $50.00 annually, $25.00 to retirees, $15.00 to students.

La SNC procure aux Canadiens intéressés à l'énergie nucléaire un forum où ils peuvent participer à des discussions de nature technique. Pour tous renseignements concernant les inscriptions, veuillez bien entrer en contact avec le bureau de la SNC, les membres du Conseil ou les responsables locaux. La cotisation annuelle est de $50.00, $25.00 pour les retraités, et $15.00 pour les étudiants.

Editor / *Rédacteur*
Jatin Nathwani (416) 592-6855

Associate Editors / *Rédacteurs associés*
Hugues Bonin (613) 541-6613
Keith Weaver (416) 592-6771

with only five minutes remaining in which to decide. It was a conference at which problems and questions elicited solutions, suggestions and courses of action rather than furrowed brows and nervous ticks.

All this occurred prior to the warning, delivered two weeks later, that expanded use of fossil fuels may be drying up as a long term energy option, with potentially an increased relative importance for nuclear energy.

On the skids? Hardly.

The Answer Lies in the . . . Water?

In the early 1960s, a work was published in the Soviet Union which concerned the effects on water of condensing it in capillary tubes. The water thus produced, which was initially called "anomalous water", reportedly had a density, structure, boiling point and other characteristics which were very different from ordinary water. By the time news of this work reached the West, in the late 1960s, there were already a number of Soviet reports on "anomalous water". Reports soon began appearing in the West as well. Anomalous water or "polywater" as it came to be called, gave rise to much hurriedly formulated research, many claims and counter-claims and a good deal of heated general debate. Ultimately, it was demonstrated that this new form of water was really just ordinary water but that its method of generation, in capillary tubes, resulted in its contamination with silicates and other materials. The whole affair was shown to be a false scent. There was no "polywater". (The entire episode is discussed in an excellent little book called "Polywater".) Water was shown to be just water; there was nothing mysterious about it.

Until recently.

"Human basophil degranulation triggered by very dilute antiserum IgE" is the title of an article which appeared in the June 30 issue of Nature. Normally, an article with such a title would not be expected to top the reading list of most people in the nuclear industry. However, the peculiarity of the results described in this paper are of more than mere passing interest.

The experiments which the article reports basically involved diluting a goat antibody serially by factors of ten or a hundred and then testing the activity of the resulting solutions. Dilutions were extreme to say the least, with the original antiserum solution being diluted by factors up to 10^{120}. It was found that these solutions retained the ability to act upon cells for which they are antibodies and that this activity appeared in peaks with periods of six to nine ten-fold dilutions over the full range of dilutions. These results were reproducible and tests were carried out in four countries (France, Israel, Canada and Italy). Similar waves of activity were also found with other antibodies at high and low dilution.

As might be expected, the editors of Nature and the reviewers have treated these results with the utmost scepticism. The review of the paper was unusually long and thorough before the decision was taken to publish it. In an "Editorial reservation" following the paper, the editors note,

"Readers of this article may share the incredulity of the many referees who have commented on several versions of it during the past several months. The essence of the result is that an aqueous solution of an antibody retains its ability to evoke a biological response even when diluted to such an extent that there is a negligible chance of there being a single molecule in the sample. There is no physical basis for such an activity."

In addition, the lead editorial in that issue of Nature, entitled "When to believe the unbelievable", notes that this perplexing result needs much more study, reflection and testing, and warns against the hasty use of it in defence of dubious notions or doctrines. The results, they note, "are startling not merely because they point to a novel phenomenon, but they strike at the roots of two centuries of observation and rationalization of physical phenomena." Considerable restraint should be exercised when approaching these results, since "when an unexpected observation requires that a substantial part of our intellectual heritage should be thrown away, it is prudent to ask more carefully than usual whether the observation may be incorrect."

There are probably no parallels of significance between these results and the polywater affair, but there is one intriguing similarity. Both involve water, a substance so common, so important and so pervasive that one would think it had been studied to death by now and understood from almost every angle. This is certainly not the case. Even in terms of its most common properties there are questions: why its boiling point is so high, how it is that water can contract when heated to four degrees above its melting point, why water has such a large heat capacity.

One should perhaps muse on such mysteries from time to time, but in keeping with the restraint recommended by the editors of Nature, there's no real need to look suspiciously at the steam tables. Yet.

Interested in Contributing to the *CNS Bulletin*?

To submit original articles, letters, FYI items, reviews, calls for papers, etc., contact one of the following:

- **J. Nathwani, Editor**, *CNS Bulletin,* c/o Ontario Hydro, 700 University Avenue, Toronto, Ontario, M5G 1X6.
- The *CNS Bulletin,* c/o the CNS office.
- Your branch or division representative.

Article

A Guide to Nuclear Power Enquiries in Canada

If you find it mind-numbing trying to keep up with all the committees, panels and enquiries looking into nuclear power these days, there's a reason. In the past 12 months there have been at least six: four federal and two provincial. Four of them are still in progress.

Looking to the future, federal Energy Minister Marcel Masse has announced that the spent nuclear fuel disposal question will be subjected to a federal environmental assessment.

Sooner or later (probably later), the results of all these enquiries will come before their respective governments and form part of the policy-making process.

At the moment the federal list is as follows:

– the New Democratic Party's independent enquiry into nuclear power, which began back in the autumn of 1986 and will likely report in the run-up to a federal election;

– the Standing Committee on Environment and Forestry, which held hearings last year and published its *Eleventh Hour* report on nuclear waste disposal last January;

– the Energy Options study, a 22 member expert panel commissioned by the federal government last year to look into energy prospects and whose report was scheduled for mid-summer;

– the Standing Committee on Energy Mines and Resources, which continues to look into the economics of nuclear energy;

– Marcel Masse's environmental assessment of the spent fuel disposal concept.

The provincial list includes:

– the Select Committee on Energy, created last February, which will examine Ontario Hydro's Demand Supply Planning Strategy this summer and autumn;

– the Hare Commission on the safety of Ontario's reactors, whose report was covered in the last issue of the Bulletin.

To the jaundiced observer all this may simply be regarded as an illustration of the old adage that "nothing exceeds like excess", but it's probably worthwhile to take a look at the players, their roles and, most importantly, what's driving the whole process.

The NDP enquiry is fairly easy to grasp. The federal conservatives had made a half-hearted promise, while in opposition, to hold an independent nuclear enquiry. When they didn't do it, and Chernobyl came along, the NDP moved into a political vacuum that was natural for them. New Democrats Ian Waddell and Bill Blaikie, and one staffer, held hearings here and there across the country, including Toronto, enjoying some publicity in the early stages at least. Ontario Hydro even sent them a brief. This enquiry enjoys no standing with the Government, but its report will be read.

The Environment and Forestry Committee got itself quite a profile last winter with *The Eleventh Hour*, but had no mandate from the Mulroney government – it simply took advantage of a new House of Commons rule which permits committees to study pretty much whatever they like, providing it falls within the terms of their mandates (loosely speaking) – and who could argue that spent fuel is not related to the environment?

Incidentally, the idea behind this rule was to provide Mr. Mulroney's many backbenchers with an opportunity to develop a public profile, something which becomes rather difficult when 281 people are trying to do just the same thing.

However, although *The Eleventh Hour* was uncalled-for, so to speak, its authors are elected representatives and they did a credible job of articulating public fears surrounding the waste disposal issue – even going so far as to call for a moratorium on further nuclear energy development.

In the federal government's response to this report, Mr. Masse thanked the Committee for its review, but rejected both the moratorium and the allegations of certain interest groups regarding the competence of people in the disposal research programme. This response goes part way towards positioning the Mulroney government where it wants to be on the nuclear issue, but not all the way – the feds will also want to set the stage for their plans after the election.

Which brings me to the last two players in this drama: the Energy Options Study, which will articulate an expert, dispassionate view of nuclear's place in the scheme of things; and the Standing Committee on Energy Mines and Resources whose report (due this autumn) on the economics of nuclear energy should say something about costs and alternatives – something to further offset the negatives in *The Eleventh Hour*.

The important difference between the two above enquiries and those of the NDP and the Environment and Forestry Committee is that the former have mandates, and the federal government is likely therefore to give them more weight when decisions are finally made.

This plethora of enquiries does give a lot of opposing interests a piece of the nuclear pie and ensures a wide public airing of the many and disparate views of the issue.

Finally, if you're a politician, with an election on the horizon, you want people to pay attention to you. And what better way to ensure that, than by grabbing headlines with an emotionally charged issue like nuclear energy?

Richard Furness

Perspective

The Case That Never Was: Sherlock Holmes' Views on Radioactive Waste

Adapted from a talk given by Professor Les Schemilt of McMaster University and Chairman of the Technical Advisory Committee to the Canadian Nuclear Fuel Waste Management Program at the June 1988 CNA / CNS Annual Meeting in Winnipeg.

Prologue

Perhaps the best known fictional character ever created, Sherlock Holmes is a legend come to life. This 19th Century detective, with his amazing analytic powers and his devotion to the logical and scientific pursuit of the criminal has, along with his faithful friend and chronicler Dr Watson, become a household name throughout the world. A vast body of literature, both scholarly and popular, has been generated. Films abound and even musicals have been produced. Scores of societies have been founded and given rise to a host of journals and newsletters in which Holmes' life and activities are subjected to detailed dissection in the best scholarly tradition.

It must be understood by those not versed in the Sherlockian convention that these activities are founded upon the premise that Sherlock Holmes was indeed a living character, that Dr Watson was his published chronicler and that Sir Arthur Conan-Doyle, mistakenly identified as the "author" by an uninformed public, was in fact a literary agent.

With this firmly established we can proceed to reveal, for the first time, the contents of some recently discovered notes by Dr Watson which are of particular interest since rather than detailing specific cases they comprise a series of observations and discussions with Holmes about the detective's plans to pursue a certain line of chemical research in his retirement years. A fitting title, then, is "The Case That Never Was", for which we shall first recall the "chemical background" to the career of the world's greatest detective.

Chemical Background

The first issue of the first Volume of the old series of the *Baker Street Journal* contained an article "Sherlock Holmes the Chemist" in which the Canadian authors establish the chemical *leit motif* running "true and steady" through Holmes' career. It began with that historic meeting between Holmes and Watson in January 1881 (*A Study in Scarlet*) in the laboratory at Barts (St Bartholomew's Hospital) where Sherlock Holmes has just discovered a reagent precipitated by haemoglobin and by nothing else. A remarkable achievement, this distinctive and highly sensitive (one part in a million) test superseded the old guaiacum reaction.

Young Stamford, who introduced the two, had earlier described Holmes as a "first-class chemist".

Dr Watson early recognised Holmes' 'profound" knowledge of chemistry and, later, observed that chemistry was "Holmes' hobby, his real love". Frequent are the references in Watson's accounts, to Holmes' turning to his chemical experiments.

Holmes' devotion to chemical research and experimentation dates back to his student days at Cambridge. In the "Gloria Scott" case Holmes notes "all this occurred during the first month of the Long Vacation. I went up to my London rooms where I spent seven weeks working out a few experiments in organic chemistry". This absorbing interest in chemistry continued throughout Holmes' career and into retirement. And during 1891-94, when the master detective had gone underground following his confrontation with Moriarty, he had found time to engage in "research into the coal tar derivatives" at Montpellier.[1]

Holmes' continuing interest and involvement in chemical research is clearly established even though Watson's published records reveal but rare instances of direct application to his criminal cases. It is at odds with Holmes' character that he would pursue anything without some plan and over-riding purpose. Upon what problems, then, did he turn his chemically related efforts and abilities?

Other related questions arise. Why are there so few details given of his efforts and travels during the "missing years" 1891-94? Why was there a period of no reported activity from late 1895 to late 1896, when it was clear that his professional practice was at full flood? Why do Watson's records make no reference to the leading contemporary advances in chemical science or to Holmes' attendance at Royal Institution Discourses, the principal public forum for reporting and discussing new advances. Why does Watson never mention any recourse to those chemistry reference books which must have occupied space on Holmes' shelves? Surely the cry "Watson, reach me that volume of Watts[2], if you please" must have been frequently on Holmes' lips.

Finally, of course, there is the mystery of Holmes' retirement at the comparatively early age of 49. It is certainly true that subsequently he spent two years in the service of his country as he planned and executed the elimination of von Bork's vast spy network in 1914 – but even then he had only reached his 60th year.

While there are some clues in the published canon, more definitive answers to all these questions have had to await the recent discovery of a slim packet of what are unarguably typed transcriptions of hitherto unpublished notes by Dr Watson.

The Watson Notes

There are three separate notes together with an explanatory note Watson must have added for his own future reference to aid him in subsequent classification and, perhaps, planned publication. The covering note reads:

"These papers are assembled under a

common chemical theme. The papers document no case. There is no criminal. But it is clear that over the years I had accumulated the information, now assembled here, that may answer some of the questions of those who, like myself, wondered about the true extent of the activities of Sherlock Holmes, in his retirement.

John H Watson"

Watson's First Note

It was the morning of December 1st, 1895 when Holmes broke his usual quiet perusal of *The Daily Telegraph* with a sudden exclamation. "It's about time, Watson! At last I can see some sign that woolly-minded old England is beginning to wake up to the importance of science."

" – what on earth do you mean, Holmes?" I asked, somewhat startled by my friend's vehemence.

"I mean, Watson", said Holmes with some enthusiasm, "that Professor Ramsey yesterday evening received the Royal Society's Davy Medal[3] in recognition of his work on argon and his discovery of helium – not really before time, since both the French and the Americans have already honoured him". My surprise at Holmes' warmth on this topic must have showed on my face, since Holmes continued: "you must remember, old friend, that though, as you faithfully chronicle, I have had some modest success in my criminal cases, I do sometimes look beyond crime – at least into the chemical world."

"Indeed you do", I responded, in a somewhat rueful tone as I glanced at Holmes' stained chemical bench, the site of so much malodorous activity. Holmes caught my glance and laughed.

"Indeed you are the most long-suffering of companions" he said, paused and then continued in a more serious tone, "Watson, I tell you that a new era in chemistry is beginning. And there will be other names as well as Ramsay's on everyone's lips before long."

"From Cambridge?" I enquired – "From Paris" Holmes responded, "one is the Frenchman Curie[4], and the other a Polish student[5] – obviously brilliant. I met them on my way back to London last year."

"But you were at Montpellier Holmes, surely" I responded with the chagrin of a biographer caught out on a minor inaccuracy.

"True, Watson, and it was Jacques Curie[6] at Montpellier who recommended that I call upon his brother Pierre in Paris since his interests appeared to be so akin to mine. This turned out to be true, and I hope to repeat my visit. The man has a perfect genius for devising scientific instruments and although he is a physicist and working on magnetism, we both share a common interest in the beautiful symmetry of crystals". Holmes paused for a moment, then continued with a trace of chagrin, "Lord Kelvin found him first – he visited Curie six months before I did"[7]. Again Holmes paused, then, in a more contemplative tone, added "You know, Watson, I've often thought that someone, somewhere, should establish a world-wide annual scientific prize for the most important scientific advance of the year . . .[8] though as I've always said to you, the work itself, with its successes and failures, is reward enough".

End of Watson's First Note

Dr Watson's Second Note

It was an early Friday evening in late 1904. My last patient had left and I was glancing through the latest issue of the *British Medical Journal* when I was surprised to hear a ring at the door. Some muttered conversation in the hallway followed and then into the room strode Sherlock Holmes. "My dear fellow!" I cried with undisguised delight, "what on earth drags you from that pleasant Sussex retreat of yours to grimy old London?"

"Even as confirmed a rustic as myself can still feel the pull of Covent Garden or the British Museum from time to time" said Holmes, flinging himself into a chair, "however, old friend, tonight I have a rather different destination planned and, were you at liberty this evening, I had planned to invite you to accompany me".

"I should be delighted, Holmes" I said, "but where?"

Holmes passed me a cutting from *The Daily Telegraph*; "There it is Watson – a very special speaker indeed at tonight's Discourse of the Royal Institution".

I glanced quickly at the scrap of newsprint. "But who is this Rutherford, Holmes?" I asked, "I do not recollect an entry for him in your *Who's Who*". Holmes got to his feet with some alacrity and, as he ushered me towards the door began his explanation. "He's a New Zealander by birth, Watson, and one of the most original minds in the scientific world. He presently works with Soddy at McGill University in Canada, and tonight his topic is 'The Radiation and Emanation of Radium'. The world will look a very different place, I suspect, when his researches are completed. He has studied at Cambridge and, Watson, I'd be prepared to wager that he'll return to the Cavendish one day, but to a Chair rather than a laboratory stool"[9].

This colloquy, it should be understood, was punctuated by our departure from my house and hailing a cab. "21 Albemrale Street, driver" cried Holmes, "and an extra half-crown if you make it in less than twenty minutes". The cabby needed no further encouragement and we rattled off at a tremendous rate to arrive at the famous lecture hall with ten minutes to spare. Inside Holmes sat on the edge of his seat, gazing quickly and observantly around the assembly and acknowledging the occasional greeting.

The distinguished speaker was a splendid example of the type of manhood that the Colonies of the British Empire seem to nurture with such prodigality. Rutherford was imposing in stature and delivery, bursting with vibrant enthusiasm and totally devoid of those intimations of pomposity and self-importance that tend to afflict our more senior *savants*. Unfortunately for me I was unable to follow completely his line of argument and, I must admit, found my attention wandering. Holmes however paid sufficient attention for both of us and, as we rose applauding at the conclusion of the lecture, said "What a phenomenal discourse. Mind me, Watson, he will be back on that platform again!"[10]

Holmes remained taciturn on the journey home, obviously still absorbed by what Rutherford had said. The following morning, as he made preparations for his departure, he was clearly still preoccupied. But he parted with a brisk step and the valediction "Watson, I have work to do in Sussex, and if all goes well I may have something to show for it in a week. Why don't you take the early train down next weekend?"

Thus it was that a week later, with a familiar thrill of anticipation, I was standing by Holmes and his stained chemical bench in what had once been the best parlour of Holmes' rambling Sussex farmhouse. Holmes looked gaunt and tired, but his eyes still held their old flame. "It's been too exciting a time to leave the bench, Watson" he remarked, when I expostulated with him about his condition, "I've managed to get some good use from the electroscope and the results speak for themselves".

"Is that the electroscope?" I asked, pointing to a cylindrical piece of apparatus on the bench, "I remember it from Baker Street, of course, but you rarely used it then".

"It's in use now, Watson" he said, making a long arm for the instrument and pulling it towards us, "but see how I've attached this telescope to this side aperture. Light enters the opposite aperture to illuminate the gold leaf. I can now measure, with great accuracy, the emanation from any sample of ore when I place it between these two metal plates. The rate at which the charged gold leaf falls tells me the quantity of emanation from the sample".

"And you are measuring these?" I asked, gesturing towards some small grey stones and a few heaps of clay-like material set on a tray at one end of the table.

"Exactly" responded Holmes, "But now let me tell you the rest of it over lunch".

Thus it was I learned of how Holmes' visit to Pierre Curie bore fruit not just in the form of the electroscope, but also (in subsequent visits) in the form of numerous samples of Austrian uranium ores and samples of the residues left following the extraction of polonium and radium. It was the residues which seemed to arouse Holmes' most intense interest.

"You see Watson", Holmes continued "as Rutherford and the Curies have demonstrated, these new areas of chemical science require a professional approach and facilities far beyond what a retired dabbler like myself can assemble. But it does amuse me to verify some of the work they do, and then there's always the possibility of finding some hitherto untravelled avenue. You might remember, Watson, one of my investigations which you recorded dealing with baryta".

"Yes indeed!", I broke in, "it was the sulphate".

"Good old Watson! As ever you recall everything but the important detail – it was

bisulphate of baryta! In any case, Madame Curie was kind enough to express some interest in that little work of mine. And, as is well known now, it is from the barium family that radium is extracted".

I freely confess that I was considerably less than enlightened by this. Some of my confusion must have shown in my face, for Holmes concluded his discourse with the words "I shall perhaps prepare a small monograph on this, once I've completed my visits to the old Cornish lead mines and the uranium deposits which have been found nearby. And that, Watson, should help answer many of your questions".

End of Watson's Second Note

Dr Watson's Third Note

I write this on 3rd August 1914. With von Bork off our hands we enjoyed our lunch at Claridges, despite the pall cast by the awful prospect of the inevitable carnage resulting from the clash of two nations mighty in science and industry. Holmes, as always, read my mood with accuracy. "You are right, old friend. This will not be 'all over by Christmas', nor I fear for several Christmases. That cold east wind will blow for longer than most suspect. But we'll come out of it perhaps a little wiser than before. Change is sometimes painful, but always exciting". I must have looked a little sceptical, for Holmes continued with some energy "I don't mean just the political changes among petty European princelings, Watson, but the changes in the way we view the natural world. We may see political revolution, but we will certainly see scientific revolution!"

"So you propose to continue your chemical researches?", I enquired. "There's no certainty" responded Holmes, "though I cannot deny the attraction. But whatever contribution I may make, I can give you two words to mark well: extraction and separation".

"What do you mean, Holmes?", I asked with some perplexity.

Holmes settled back in his chair and continued, "Well, they describe precisely how I was able to achieve that unique reagent for haemoglobin, why coal-tar derivatives can be selected to perform some very special separations and how the Curies obtained radium from pitchblende. The question then arises, Watson, as to the role of the residues. And to that of radium itself. We know that the radium emanation has powerful and good uses – but it has dangers also. Do the residues? And if so, how are they rendered harmless? That is the problem foreseen by certain well-known investigators and one which has captured my attention for a long while.

"There is an interesting parallel, Watson, with the problem the criminal poses society. It takes a certain special aptitude to find and isolate the criminal elements – and yet how necessary that they be separated and disposed of properly and safely. My career has been devoted to ensuring such efficient extraction – it is at least one way to break that 'circle of misery and violence and fear'. It is equally challenging, is it not, to look at the world of nature and try to separate the good and useful from the bad and dangerous. After all, Watson, the tincture of belladonna you carry in your medical bag is a safe and useful medication. But the lethal belladonna from which it is extracted is fittingly named 'Deadly Nightshade'.

"How important it is to establish the facts before attempting to reach conclusions – as I have frequently said to you, Watson. Perhaps now my role will simply be to establish some of those facts – contribute some of the data – so the foundations can be laid".

End of Watson's Third Note

Discussion

While Watson's notes do not fully answer the questions about Holmes' retirement activities, they do emphasize his continuing chemical interests, his election of the study of radioactivity and his interest in the handling of radioactive wastes. As well, we can note that throughout the whole canon we can find guidance, insight and wisdom in this important area of endeavour. Holmes' edicts of requiring verifiable data, not ignoring ascertained facts, the application of objective judgment, careful deduction, precise observation and measurement and giving due weight to probabilities provide a superlative methodology for the successful pursuit of any scientific investigation.

Conclusion

There remain mysteries and problems within mysteries. So long as we have need of application of scientific reasoning with the use of verifiable data, then Holmes will be with us. He's certainly with us in the chemical field, as can be seen from Volume 75 (1971) of the *Journal of Physical Chemistry*. In an article entitled "Kinetics and Mechanisms of the Carbon Disulphide-Oxygen Explosion" it is noted that appropriate selection of the complex mechanism depends on using "the method of Holmes". The reference footnote reads: "S Holmes has successfully demonstrated the power of the intriguing argument that if only one possibility exists, it must be true, no matter how implausible it may seem".

Sherlock Holmes still at work? Now and Forever!

Notes

1. Site of a well-known university with famous faculties of medicine and science.
2. Watts' "Dictionary of Chemistry", Vol. 1 was published in 1870.
3. Sir William Ramsay received the Davy Medal Nov. 30, 1895.
4. Pierre Curie joined the School of Physics and Chemistry in Paris in 1883.
5. Marie Sklodovska visited the Sorbonne in 1891.
6. Prof. Jacques Curie became Professor of Physics at Montpellier in 1883.
7. Lord Kelvin visited Curie in Paris on Oct. 5, 1893.
8. The first Nobel prizes were awarded in 1901.
9. Rutherford received a Nobel prize in 1908 and assumed the Chair at the Cavendish in 1919.
10. Rutherford lectured on "Radioactivity" at the Royal Institution in 1908.

Book Reviews

A Brief History of Time: From the Big Bang to Black Holes, Stephen Hawking, Bantam Books, New York, 1988, ISBN 0-553-05340-X.

"My goal is simple. It is complete understanding of the universe, why it is as it is, and why it exists at all."

Stephen Hawking made these apparently arrogant statements in 1981. Seven years later, in his book *A Brief History of Time*, their meaning seems to come through somewhat differently, and is perhaps summarized most elegantly by Carl Sagan in his introduction to the book.

"This is also a book about God . . . or perhaps about the absence of God. The word God fills these pages. Hawking embarks on a quest to answer Einstein's famous question about whether God had any choice in creating the universe. Hawking is attempting, as he explicitly states, to understand the mind of God."

In its 175 pages of text, *A Brief History of Time* tries to cover a great deal of ground. In fact it tries to cover all of it. Beginning with the Ptolemaic and Copernican systems and working forward, the book rapidly overtakes Maxwell, Michelson-Morley, Einstein, Hubble, Heisenberg, etc., etc. One soon begins to wonder whether the title is appropriate. Are we really reading about the history of time?

Historical (in the sense of written history) aspects of time certainly do make their appearance. Augustine's well-known comment about time (he knows what it is until somebody asks him but then he doesn't know what it is) makes an appearance, as do the conceptions of Aristotle, Newton and others. But as we approach the present and the plot thickens, any discussions of time become integral with the increasingly complex physics. This is not to say that the discussion is highly technical and full of equations, but rather that it drifts further and further away from what the average person would call "reality". Eventually, at the centrepiece of the book, Hawking's discussion of black holes and the fate of the universe, speculation is presented as to whether time "stops", "reverses" or is imaginary (in the mathematical sense), meaning that it merges with and becomes indistinguishable from space mathematically.

This is all heady stuff, even for the most informed of laymen. By the end of the book it

TECHNICAL SUPPLEMENT

CNS Bulletin July/August 1988 Canadian Nuclear Society

NONDESTRUCTIVE TESTING AND IMAGING USING RADIATION SCATTERING*

ESAM HUSSEIN

Department of Chemical Engineering
University of New Brunswick, P.O. Box 4400
Fredericton, New Brunswick E3B 5A3 Canada

ABSTRACT

Nuclear radiation has long been used in many nondestructive testing (NDT) applications. The attenuation of transmitted radiation is the modality usually employed. Radiation scattering, on the other hand, has played a lesser role in NDT, despite the rich information and the flexibility it offers. This paper examines some methods by which the scattering of gamma rays or neutrons is exploited for industrial and medical NDT purposes.

INTRODUCTION

Nuclear radiation, because of its ability to penetrate the matter, has been utilized in many NDT applications. Radiography is perhaps the most known and widely used form of radiation NDT. Computer assisted tomography is another familiar technique that is being used for medical purposes and is increasingly being exploited for many industrial applications. Radiography and tomography are both based on the measurement of the degree of transmission of the incident radiation through the object.

An alternative radiation interaction that can be utilized for examination purposes is radiation scattering. Radiation scattering, unlike transmission, does not require access to both sides of the object and provides a measurement that is strongly related to the density of the inspected material. Scattering also allows changes in composition to be monitored. In addition, scattering provides point-wise information that can be utilized to inspect isolated points in the object or construct three-dimensional images. Internal flaws or structures can, therefore, be measured and located in three dimensions. Moreover, scattering is capable of diagnosing light materials surrounded by more dense material; a situation not resolved by radiography and causes a reduction in resolution and quality of tomographic images.

The purpose of this paper is to explore some of the techniques and applications of radiation scattering. The paper focuses on techniques that employ the scattering of either photons (X- and gamma radiation) or neutrons.

X- AND GAMMA RADIATION SCATTERING METHODS

Physical Principles

When a photon is scattered by interaction with the tightly bound atomic electrons, an elastic scattering results in which the energy of the incident photon does not change. This type of elastic coherent scattering is known as Rayleigh scattering. The process occurs mostly at low energies and for high Z (atomic number) materials.

On the other hand, when the scattering of a photon causes an electron to recoil with respect to other electrons, an inelastic scattering occurs and the electron recoils out of the atom as if it had been initially free. This is the well known Compton scattering, a dominant mode of interaction for most materials in the photon energy range of 50 keV to 1.5 MeV.

Compton scattering provides a direct measure of the electron density (electrons/volume) of the medium. The probability of scattering is directly proportional to the Z number of the medium. The mass density of the scattering medium or its composition can be deduced from the electron density, based on physical grounds or calibration measurements. The photon energy following a Compton scattering is given by the relationship:

$$E' = E / [1 + E (1 - \cos\theta) / mc^2] \qquad (1)$$

where E and E' are the incident and scattered photon energies, respectively, θ is the scattering angle, and mc^2 is the electron rest mass (511 keV). This equation provides a unique relationship between the energy and angle of scattering. By measuring the energy spectrum of singly scattered photons, the

* This is a short version of a paper by the same author to appear in International Advances in Nondestructive Testing, Gordon & Breach, New York.

elements (points) and sequential evaluation of the element densities starting with those points closest to the source and detector. The scanning process is elaborate and is not easy to implement in many practical situations. Another proposed method relies on aligning the density points along isogonic (equal-angle) scattering lines and using a set of multiple sources and detectors at fixed locations (8). A number of measurements equaling, at least, three times the number of image elements can then be recorded. The three unknowns associated with each imaging element, the density and the attenuation factors, are then determined by solving a set of linear algebraic equations. A direct inversion method for solving the attenuation problem has been proposed (9). This method evaluates the effect of attenuation iteratively by inverting a scattering matrix that incorporates the attenuation factors.

Tomography of several small inclusions (in the rods, plates, and spheres) embedded in a metal plate have been reported by Stokes et al. (5). The atomic number and density of these inclusions were higher than that of the metal plate, enabling adequate determination of the location and spacing of inclusions. Imaging of aluminium castings has also been reported (10). Compton profile measurements has been used to determine the spatial distribution of flow phases in channels. Medical applications of Compton scatter imaging are reported elsewhere (3). An X-ray backscatter imaging technique has also been recently proposed (11).

Composition Measurement

Most composition measurements rely on the use of the Rayleigh-to-Compton scattering ratio, as explained earlier. The area under the Compton profile is usually used as the Compton signal. The Rayleigh-Compton scattering ratio has been used for measuring changes in titanium-rich alloys with aluminium and zirconium as well as for measuring the surface composition of heavy elements. The method has also been applied to the determination of the effective atomic number of compounds of atomic numbers of less than 20. The ratio technique has been used to measure the concentration ratios in substances of major compounds of low atomic number, such as fat, water content in milk products or in meat, and reaction products in organic chemistry. In principle, however, the effective atomic number of materials of $Z = 6$ to $Z = 83$ can be determined by the Rayleigh to Compton scattering ratio.

Medical applications of the Rayleigh to Compton scatter ratio include the measurement of fat in liver, trabecular bone mineral density, bone density and stable iodine content in tissue. Elemental scattering using the Compton profile as a "finger print" has been used to analyse the chemical properties of tissue.

Small angle coherent (Rayleigh) scattering has been proposed recently to complement conventional transmission tomography (12). This enables the determination of composition characteristics of some biological tissues and plastics that cannot be resolved by transmission tomography alone.

NEUTRON SCATTERING METHODS

Physical Principles

Neutrons interact with the nuclei of the matter. They are also affected more, in terms of energy loss, by low mass number materials than by heavy elements. Neutron diagnosis provides, therefore, good contrast for hydrogenous and hydrocarbon materials. Furthermore, neutrons easily penetrate the thick metallic walls that may contain these materials.

The scattering of epithermal and fast neutrons results in an appreciable energy degradation that depends on the density and type of the examined material. Neutron elastic scattering is governed by particle kinematics that results in the following relationship between the energy and angle of scattering:

$$E'(\theta) = E\left[(1 + 2A\cos\psi + A^2) / (1 + A)^2\right] \qquad (4)$$

where E and E' are the incident and scattered energies, respectively, A is the mass number of the scattering nucleus, and ψ is the scattering angle in the center-of-mass system. The corresponding angle in the laboratory system, θ, is given by the relationship:

$$\cos\theta = \left[1 + A\cos\psi\right] / \left[1 + 2A\cos\psi + A^2\right]^{1/2} \qquad (5)$$

Equation 4 is fundamentally similar to that of the Compton scattering, equation 1, in the sense that both result in a unique angle-energy relationship that enables the utilization of the energy spectrum of the scattered radiation to determine the direction of scattering. The concepts of local measurements and imaging used for Compton scattering are, therefore, equally applicable to neutrons.

Applications

Neutron backscattering from a rock matrix is used in drill hole logging to identify water, oil and natural gas bearing strata (13). The porosity of an earth formation has also been determined by neutron scattering. Porosity is directly related to the concentration of hydrogen in the formation.

Neutron scattering has been also proposed for detecting the presence of ground bottom support of submerged pipelines. The detected neutrons are used to determine the type of medium outside the pipeline and whether the pipeline is bottom supported.

Since neutron scattering is strongly affected by the presence of hydrogen in water, it has long been employed to measure moisture in large samples of coal, soil, concrete, and roofing materials (14, 15). Neutron scattering techniques have also been developed for measuring the average void fraction of a vapor-water flow in a pipe (16). The scattering of neutrons in heavy water and the high thermal-neutron absorption cross-section of gadolinium have been utilized in designing a nonintrusive device for monitoring the concentration of the gadolinium nitrate solution employed in the liquid injection shutdown system of CANDU reactors (17).

Neutron scattering has not yet been fully exploited for local inspection or imaging applications. However, a neutron scattering system for section imaging of a two-phase flow in a pipe has been recently developed by the author and coworkers (18). This single exposure neutron tomography (SENT) technique utilizes an inversion method for solving the attenuation problem that accompanies scatter imaging.

CONCLUDING REMARKS

Radiation scattering carries information on density,

direction of scattering can be determined. Since the flux of the scattered radiation is proportional to the electron density along the direction of scattering, a set of scattering data in different directions can be combined and unfolded to produce an image of the scattering geometry.

Global Examination

A global, or bulk, measurement is defined here as a measurement that provides information conveying the status of the entire body of the examined subject. This is particularly useful for surveying measurements or quality control applications. Global measurements are also useful for average density, concentration and thickness measurements.

Wide radiation beams can be used in performing global measurements, thus, source collimation is not necessary. The scattering intensity at small angles (forward scattering) can be approximated to a second order by (1):

$$S = a\,(\rho\,\mu\,d)\,[1 - b\,(\rho\,\mu\,d)] \qquad (2)$$

where μ is the mass attenuation coefficient, ρ is the material density and d is the equivalent diameter of the scattering area, and a and b are system-dependent constants. The scattering area is a region defined, by the intersection of the incident beam and the detector view area.

For backscattering, the scattering intensity can be expressed semiempirically by (2):

$$S_b = a\,(\rho\,\mu\,d)^b \exp\,(-\rho\,\mu\,d)\,/\,d^2 \qquad (3)$$

where a, and b are again some system-dependent constants and d here is the source-to-detector distance.

Both equations 2 and 3 indicate that the scattered photon flux is a strong function of the product $\rho\mu d$, from which density, composition and geometry information can be extracted.

Examples of global scatter systems include: thickness gauging of aluminum, concrete, carbon bricks and wood; measurement of the concentration of heavy atoms in low Z media; density of two-phase flows, wood blocks and carbon bricks; and moisture content. Global scattering has also been in use, for some time, in the measurement of soil density, in fluid-level indication and in rock formation density measurement of borehold probes. Rayleigh scattering alone has been investigated for measuring density changes in bone equivalent material.

Local Examination

By narrowing both the width of the incident beam and the view area of the detector, scattering measurements can be focussed on a small volume, or a point, in the medium. This enables localized inspection of isolated points. The incident beam width can be reduced by collimation of the radiation source. The detector view area can be limited to the desired size by equipping the detector head with a collimator, or alternatively by analyzing the pulse height spectrum of the detector. The latter determines the energy of the detected radiation, which in turn is related to the direction of scattering, as equation 1 shows for Compton scattering.

The detector signal depends not only on the electron density of the scattering point but also on that of all points along the incident and scattered radiation paths. It is, therefore, necessary to compensate for this attenuation effect in order to be able to use the scattering signal to calculate the electron density at the desired point. This can be achieved by employing supplementary transmission and scattering measurements to provide sufficient information to correct for attenuation (3).

Another problem that reduces the resolution of images produced by Compton scattering is caused by multiple scattering. This leads to an additive component in the scattering signal that is dependent on other points surrounding the monitored volume. The effect of multiple scattering can be reduced by proper detector collimation, by energy discrimination to reject energies not corresponding to single scattering, or by system calibration (3).

Local measurements using collimated beams has been used for inspecting structures for the presence of cracks, inclusions and voids (4). Inspection of aircraft engine turbine blades for the casting defects has also been carried out successfully for defect volumes of 0.4 x 0.4 x 3.4 mm^3 (5). Measurement of local void fraction in complex two-phase flow geometries has also been reported. Local scattering has proved useful for rapid screening of manufactured items, such as detecting missing igniter pellers in armed fully primed 25 mm ammunition (5). Other military applications include an automated inspection device for explosive charge in shells (6). This device is used for inspecting artillery shells for the presence of voids, cracks, porosity and separation between the explosive filter and the steel shell case within inspection volumes of 2.8 x 2.8 x 5.6 mm^3. Conventional radiography methods fail to detect such flaws with adequate contrast behind the steel casing of the filter. Inspection of military scrap for the existence of explosives is an other application in which the signature of the scattering signal is used to identify the distinct regions of a cartridge. The method can be used even if only one side of the item is accessible, i.e., a suspected live bomb half buried in the sand. Local scattering has been also used for lung and bone density measurements (3).

Imaging

In order to reconstruct an image from scattering data, a set of local measurements distributed over the imaging target is required. The flexibility of obtaining scattering measurements corresponding to any location in the object enables one to obtain either a section image (tomograph) or the image of a three-dimensional volume. The attenuation and multiple scattering problems encountered in performing local fixed point densitometry are, however, more difficult to overcome in scatter imaging. This is not only due to the fact that correction for these effects has to be performed for every point in the image, but also because these point-dependent effects are strongly coupled to each other. Nevertheless, a number of methods have been developed for solving the attenuation problem in scatter imaging. The multiple scattering problem has been treated so far in a rather empirical way.

The simplest approach to solving the attenuation problem is to ignore it altogether by employing high energy radiation. The attenuation of the scattered radiation remains, however, significant because of the reduced energy of scattering. A point-by-point rectilinear scanning method has been proposed for solving the attenuation problem (7). The method is based on ignoring self-attenuation within the image

composition and geometry that is valuable for many nondestructive testing and imaging applications. Although scattering measurements are difficult to interpret, they provide an alternative approach that can be employed in applications for which conventional transmission (uncollided radiation) methods are not suited. The scattering method can be used for examining localized regions, does not necessarily require an access to both sides of the object, and enables the design of simple and flexible inspection systems. The variety of applications presented in this paper illustrates the wide scope of applications covered by the scattering method. This should encourage the development of new applications and the refinement of existing ones to meet the industrial nondestructive examination needs. The present state of advancement of nuclear instrumentation makes it possible to design scattering systems that satisfy the requirements of many practical applications.

REFERENCES

(1) KENNETT, T.J., PRESTWICH, M.V., AND ROBERTSON, A., "Dynamic Density Measurement by High Energy Photon Scattering", Int. J. Applied Radiation & Isotopes", 27, 529-532, 1976.

(2) MAUS, L.D., RONEY, J.R., ROSE, V.C., AND NACCI, V.A., "Modelling of Backscatter Gamma Ray Sediment Gages", Proc. ERDA X- and Gamma-Ray Symp., Conf. 760639, 186-189, 1976, May.

(3) HUSSEIN, E.M.A. AND KONDIC, N.N., "Compton Scatter Imaging Systems", in Bioelectronic Systems, D.L. Wise, Ed. (CRC Press, Boca Raton, Florida, in press).

(4) GAUTAM, S.R., HOPKINS, F.F., KLINKSIEK, R., AND MORGAN, I.L., "Compton Interaction Tomography: Feasibility Studies for Applications in Earthquake Engineering, IEEE Trans. Nucl. Science, NS-30, 1680-1684, 1983.

(5) STOKES, J.A., ALVAR, K.R., COREY, R.L., COSTELLO, D.G., JOHNS, J., KOCIMSKI, S., LURIE, N.A., THAYER, D.D., TRIPPE, A.P., AND YOUNG, J.C., "Some New Applications of Collimated Photon Scattering for Non-destructive Examination", Nucl. Instr. Methods", 193, 261-267, 1982.

(6) HOLT, R.S., COOPER, M.J., AND JACKSON, D.F., "Gamma-Ray Scattering Techniques for Non-Destructive Testing and Imaging", Nucl. Instr. Methods, 221, 98-104, 1984.

(7) BATTISTA, J.J., SANTON, L.W., AND BRONSKILL, M.J., "Compton-Scatter Imaging of Transverse Sections: Correction for Multiple Scattering and Attenuation", Phys. Med. Biol.", 22, 229-244, 1977.

(8) KONDIC, N.N., JACOBS, A.M., AND EBERT, D., "Three-Dimensional Density Field Determination by External Stationary Detectors and Sources using Selective Scattering", in Proc. on Nuclear Reactor Thermal-Hydraulics, 1443-1455, 1983.

(9) HUSSEIN, E.M.A., MENELEY, D.A., AND BENERJEE, S., "On the Solution of the Inverse Problem of Radiation Scattering Imaging", Nucl. Sci. Eng.", 92, 341-349, 1986.

(10) HARDING, E., "On the Sensitivity of Application Possibilities of a Novel Compton Scatter Imaging Systems", IEEE Trans. Nucl. Sci., NS-29, 1260-1265, 1982.

(11) TOWE, B.C. AND JACOBS, A.M., "X-ray Back-scatter Imaging", IEEE Trans. Biom. Eng., BME-28, 646-654, 1981.

(12) HARDING, G., KOSANETZKY, J., AND NEITZEL, U., "X-ray Diffraction Computed Tomography", Med. Phys., 14, 515-525, 1987.

(13) BROMLEY, D.A., "Neutrons in Science and Technology", Nucl. Instr. Meth., 255, 240-279, 1984.

(14) BERGER, H., "Practical Applications of Neutron Radiography and Gauging", ASTM Special Technical Publication No. 586, American Society for Testing and Materials, 1976.

(15) BONIN, H.W. AND THORP, C.J., "Neutron Moisture Gauge for Roofing Surveys: Experiment and Simulation", Proc. 5th Annual Conf. Canadian Nuclear Society, Saskatoon, Saskatchewan, 48-53, 1984, June.

(16) HUSSEIN, E.M.A., "Simulation and Design of a Neutron Scatterometer for Void-Fraction Measurement", Nuclear Engineering and Design", 105, 333-348, 1988.

(17) HUSSEIN, E.M.A., O'CONNOR, D., AND MOSHER, M., "A Non-Intrusive Neutron Method for Gadolinium Poison Concentration Monitoring in Candu Reactors", Nuclear Journal of Canada, 1, 46-52, 1987.

(18) HUSSEIN, E.M.A., MENELEY, D.A., BANERJEE, S., "Single Exposure Neutron Tomography of Two-Phase Flow", Int. J. of Multiphase Flow, 12, 1-36, 1986.

seems apparent that time has been used as a convenient (a necessary?) hook on which to hang the entire laundry of physics. Instead of being a review of various people's understanding of time through the ages, Hawking's presentation depicts time as an aspect of the still vague and imperfectly seen substrate on which the remainder of his story rests. But even as new concepts and new techniques are brought into play to refine an already esoteric understanding of physics, time, an apparently fundamental and mundane entity, shows new facets as it drifts further off into the mist, a Beatrice to our Dante.

A Brief History of Time is far too brief for my taste. Although the writing is lucid, it is very condensed and a good many of the concepts Hawking describes could have been profitably held up to the light a little longer, examined at greater leisure. There are also odd changes in depth of focus. At one point several sentences (relative loquacity by Hawking's standards) are spent explaining the Doppler effect, including a reference to its use in speed radar. In contrast, elsewhere in the book the reader is presented with some quite involved aspects of superstrings and black holes, much less common, one would think, than police radar, but these are pointed out quickly and with little ceremony, as just so many more stalactites to a spelunker. Particularly in the latter part of the book, one has to keep one's wits honed, and it helps to have a number of reference volumes on hand.

Some people, like me, may feel it a duty, in an odd sort of way, to read *A Brief History of Time*, being as it is something of a document of our age. For those people it will seem a duty lightly undertaken and easily and pleasurably discharged. *A Brief History of Time* is also a fitting and overdue glimpse into the mind of man who, whatever his faults, cannot speak, can make even the most trivial physical gestures only with great effort, but at the same time roams freely along the frontiers of physical knowledge and is the academic successor to Newton and Dirac.

Not bad.

Keith Weaver

Nucleus: The History of Atomic Energy of Canada Ltd., Robert Bothwell, University of Toronto Press, 1988. ISBN 0-8020-2760-2.

This book is a bit of a mixture – some parts are excellent, some disappointing and worrying. Uneven and inconsistent in style and depth of coverage, it does not do full justice to those men and women who have worked so hard and achieved so much in a remarkable Canadian endeavour. Also *Nucleus* presents a version of AECL's history which, on some significant technical issues, appears to be incomplete and not entirely consistent with the contemporary Canadian scientific literature. The inconsistencies are neither identified nor resolved. Two examples will be discussed later.

In his Foreword to the book, AECL President James Donnelly observes that "Nothing is as perishable, or as forgotten, as the recent past". To this it should be added that nothing is more difficult to record, analyse and evaluate in an objective fashion. With major players if not on the stage, at least hovering in the wings, and with sensitivities still fresh, the scholar who would document the very recent past has a difficult task.

It is not made absolutely clear what period of time *Nucleus* is attempting to cover. The first five chapters – covering the period from 1942 with the transfer of British scientists from Cambridge to Montreal, to the mid 'fifties with the beginning of the involvement of Ontario Hydro in a commercial power reactor programme, are highly detailed and probably the strongest part of the book. The next five, which cover the period from 1955 to about 1970 and include the evolution of the CANDU reactor and the increasing range of AECL activities at home and abroad, are much less even in depth of coverage. The two concluding chapters "Big Science" and "Epilogue; or the Price of Success" skip back and forth to include the ING (Intense Neutron Generator) project, the start up of Pickering, the growth of the isotopes businesses at Commercial Products, CANDU sales to Korea and Argentina, the detonation of India's first atomic "device" and the appointment of James Donnelly to AECL's presidency in 1978.

Early Days

Bothwell's account of Canada's moves towards involvement in, and subsequently prosecution of, a nuclear research programme is the best part of the book. He brings clarity (and the odd touch of ironical comment) to the often byzantine (and sometimes not particularly creditable) manoeuvrings between the Canadians, the British and the Americans.

British aims were quite simple, though by no means simply expressed: if atomic weapons, of unprecedented destructive power were possible, they wanted them. Their own atomic scientists at Cambridge were not only vulnerable to air attack but also were without access to adequate resources – after all not only was Admiral Doenitz's U-Boat fleet coming as close to success as it ever would in severing Britain's Atlantic lifeline, but also available equipment and human resources were dominated by the need to fight the war now; longer term projects had to be regarded as of secondary priority. For these reasons, it was felt, transferring the scientists and their equipment to Canada might be an answer. Such a move might also encourage the Americans to share information.

The American viewpoint was also straightforward. If the British were doing (or would do) work which would make a direct contribution to atomic weapon development in time for use in the current war, then maybe something could be worked out. But by no means would hard-won American know-how be handed over so that the wily British could feather their nuclear nest for post-war commercial competition with the US. Scientists from Cambridge would be perfectly welcome to come and work as part of the US programme, although the Americans had subsequently some reservations about certain members of the cosmopolitan crew from Cambridge.

In this developing dispute the Canadians found themselves rather in the position of "piggy in the middle". Clearly the personal views of some of the Canadians involved, as well as a pragmatic review of the relative geographic and economic influences of Britain and America led to a growing tendency to regard Canada's bread rather better buttered south of the 49th parallel than elsewhere. In the nuclear area Canadian relations with Britain and the US seemed to be characterized by an appropriate degree of truculence on the part of an ex-colony toward the erstwhile mother-country, in the case of the former, and an appropriate degree of conciliation and accommodation towards an economic and technical giant who just happened to live next door, in the case of the latter.

Canada's interest in maintaining US interest and involvement (or investment) in Canadian nuclear work was effectively at odds with the singleminded British determination to have her own nuclear weapons. Britain's gradual withdrawal from the Canadian nuclear scene and her establishment of an aggressive programme of research and development on her home ground was dictated by strategic considerations which, Bothwell notes, "could not be compromised by being mortgaged to a whimsical Dominion whose leadership was all too susceptible to US pressure".

Bothwell is at some pains to detail the British involvement in the early stages of Canada's nuclear programme and pays a generous (but well deserved) tribute to Cockroft's achievement in establishing Chalk River and making it a "functioning, large-scale scientific enterprise". He notes "in conception and design the NRX reactor was a farewell gift, a vote of thanks, from British atomic technology to Canada".

Bothwell's evocation of the confused early years of nuclear research in Canada, with the expatriate scientists under the somewhat temperamental leadership of Halban, is first-rate. The confusion existed at both the scientific and the government level – as Bothwell notes, "the relevant authorities in Canada imperfectly understood what they were committed to accomplish" and indeed it is possible to infer that this confusion at the government level about the objectives, capabilities and benefits of nuclear research and development in Canada has continued more or less unabated up to the present time.

Bothwell does his readers, and the historical record, a valuable service by clarifying the relationship of Canadian nuclear science with nuclear weapons development. He notes that while C.D. Howe may, in immediate response to a question in the House of Commons, have noted that Canada did not make nuclear bombs nor had she plan to do so, this statement while literally true could be construed as diversionary. It is a fact that the very inception of nuclear research in Canada was aimed at nuclear weapons production, that the Chalk River Nuclear Laboratories were set up to construct a "nuclear boiler" which might help show the way to production of weapons

material, and that construction of the major research reactor, NRU, was predicated upon a guaranteed market for plutonium produced in that reactor. Bothwell notes that C.J. Mackenzie "had no difficulty in supporting, not to say originating, proposals looking to military production at Chalk River".

People, Politicians and Technology

The history of AECL is very much a history of the people involved and *Nucleus* reflects this. Bothwell has relied quite heavily on personal reminiscence, personal interviews accounting for over 14 per cent of the almost 900 references (including, curiously enough, two anonymous "confidential" interviews). He shows a keen and accurate appreciation of the personalities involved and, indeed, of the whole human aspect of the nuclear research business in Canada. His accounts of the "quality" of life in Deep River will strike resonant chords for all who have spent any considerable time in Chalk River's dormitory town. He also, at his best, displays an urbane and sometimes ironic wit that makes parts of the book sheer pleasure to read. For example, recounting the formal "sod turning" at Rolphton to mark the start of work on NPD, he notes that after Frost and Howe had shifted the symbolic spadeful of earth and trotted off, workmen came in to clear away the pile of earth. Because of the rocky nature of the site the earth, like the politicians, had to be trucked in!

In dealing with the major players Bothwell displays perception and objectivity – his emphasis on the very major contributions by George Laurence (who has tended to be eclipsed in many people's minds by W.B. Lewis) will be read with especial appreciation by all those lucky enough to have ever met Dr Laurence. On W.B. Lewis himself Bothwell is particularly perceptive, documenting Lewis' almost evangelistic dedication to the concept of nuclear power as *the* means by which the world could be made to support all its population at a reasonably adequate standard of living. Bothwell's observation about W.J. Bennet's choice of Gray to succeed as AECL President rather than Errington is worth quoting: "Lewis was spared the experience of working under a physicist who had not merely left the profession but gone into trade" – a comment which is equally, and accurately, illuminating about all the participants.

Gray is identified as a major influence on AECL. He was a man of exceptional drive and dedication, whether it was in entertaining Ottawa civil servants to lunch or assisting in the construction of the Deep River Golf Club. Gray, Bothwell notes, "preferred not to confront an immovable object head on; he moved around obstacles, usually at speed". Perhaps there is a cautionary note in Bothwell's observation that for Gray "propriety had a cost. It was a commodity like any other".

As has been mentioned earlier, from the outset Canadian politicians really didn't know what they'd got themselves into with this nuclear power business. But Bothwell does not identify any really serious and systematic attempt by AECL to change this situation – any attempt to establish the technical realities for non-participants is notable by its absence. The AECL approach seems typified by the response to Winnett Boyd, an engineer of some eminence, who in 1959 strongly urged that attention be focussed upon the high temperature gas-cooled reactor rather than the heavy-water moderated machine and raised the question of pressure tube performance in the CANDU design. Boyd also predicted a falling off of international interest in the heavy-water reactor. C.J. Mackenzie's response to this seems, according to Bothwell, to have been limited to announcing that he would not stay in the same room as Winnett Boyd.

The dog that did not bark – BLW and ABLW

The direct cycle, boiling light-water cooled CANDU gets short shrift in *Nucleus*. Bothwell does describe how Quebec, interested in obtaining a nuclear plant on the same basis as Ontario had, i.e. with significant federal government support for a "pilot plant", was steered towards the BLW concept and the optimism with which this design was viewed – he quotes Mitchell Sharp's comment that the Gentilly-1 venture "was likely to lead to substantial sales of this type of reactor in the future". But his coverage does not, it seems to me, reflect the total scope of AECL's BLW/ABLW effort – a programme which occupied a significant amount of AECL's attention for a significant amount of time.

At the Fourth United Nations Conference on the Peaceful Uses of Atomic Energy, held at Geneva in 1971, a paper by Hart, Haywood and Pon ("The CANDU Nuclear Power System – Competitive for the Foreseeable Future") describes three boiling water CANDU variants – the original Gentilly-1 type, a version using some degree of fuel enrichment (either U-235 or plutonium) and the Advanced Boiling Light Water CANDU with a more highly subdivided (36 element) fuel bundle and an outlet steam quality of 40 per cent (compared with 20 per cent at Gentilly-1). As well, the paper notes that "We expect that a choice between the natural uranium and an enriched uranium version will be possible by 1973". The issue of fuel enrichment for the BLW concept is virtually ignored in the book, save for a quotation from Ara Mooradian that "if enrichment were permitted, a different plant would be designed and the result would be much better" with no subsequent explanation or discussion.

On the performance and ultimate fate of Gentilly-1 Bothwell has this to say:

> It (Gentilly) had its problems, but this was mainly because everyone knew that it would be shortly shut down so as to send heavy water to Ontario

and

> In 1978 Gentilly-1 was closed, primarily for safety reasons

Surely the BLW/ABLW programme deserves a better epitaph than this!

Pressure Tube Expectations

Adequate pressure tube performance has always been recognized as a key factor in the commercial viability of the CANDU system. Pressure tubes live in a rigorous environment of high temperature and pressure and intense neutron bombardment. The question "how long will a pressure tube last in a commercial power reactor?" can only receive an unequivocal answer through operating experience. Bothwell's treatment of the pressure tube longevity question is cursory and cavalier.

Bothwell argues that the expected pressure tube lifetime was about fifteen years, citing a paper presented by Foster to the Toronto Chapter of the American Society of Metals in 1964 and further commenting

> the most serious difficulty was the rate of creep . . . which, in Haywood's opinion risked having to replace the pressure tubes within the lifetime of the reactor

and

> but one thing turned out to be correct, or even slightly on the pessimistic side: the fifteen year life projected for the tubing

and concluding the discussion with the comment that "There would be, at any rate, no surprise when difficulties later developed". The only reference Bothwell makes to the failure of pressure tube G-16 in Pickering Unit-2 in 1983 is "pressure tubes sagged in the Ontario reactors, more or less as predicted, in the early 1980s".

All this is a little inconsistent with some contemporary documentation. Returning to Canadian papers presented at the 1971 Geneva conference, one paper on reactor safety (by Hake *et al*) mentions pressure tube life, in a general sense, and cites a 30 year lifetime. More specifically a paper by Evans, Ross-Ross and LeSurf ("Metallurgical Properties of Zirconium Alloy Pressure Tubes and their Steel End Fittings for CANDU Reactors") cites 30 and 40 year lifetimes – the limiting criterion being diametral creep. The fifteen year tube lifetime is mentioned in this paper in the following sentence: "In organic cooled reactors the life limiting criteria are corrosion and hydrogen (ingress); nevertheless lives of at least 15 years are predicted".

To be quite blunt about it, Bothwell's reporting of AECL's predictions of pressure tube performance seems quite inconsistent with what was reported at a major international conference in 1971 by specialists in the field. It is by no means improbable that different people at AECL held different views about long-term pressure tube performance. If that was the case, then Bothwell should have recounted it. At best, it can be said that the author has overlooked quite important technical documentation, review of which should surely have been a *sine qua non* when dealing with a technical subject with such important implications.

In *Nucleus* Bothwell has not set out to produce a technical history – his view focusses upon the people concerned and the provincial, federal and international political environment in which they had to operate. As such, heavy reliance is placed upon personal reminiscences and documentation such as minutes of meetings, memoranda and other formal and informal communications. From such sources an

impression of AECL's stance at any particular time may be obtained. However AECL is a technical organization, and its technical voice should not be totally ignored. If this 'technical voice' appears inconsistent with information from other sources, the inconsistency should be identified, explored and, if possible, resolved. Bothwell's failure to do this – particularly in the case of pressure tube performance – must be accounted a fatal flaw.

Some minor quibbles

It is possible that the book may be the victim of a hurried presentation schedule (in his introduction Bothwell does draw attention to the fact that some archival material could not be obtained in time to meet the book's deadline). Certainly *Nucleus* seems to have lacked rigorous editing and proofreading which might have caught such trivial errors as: a pressurized water reactor identified as a high temperature gas cooled reactor; the date of the Douglas Point shutdown identified as 1986; the operating pressure of a PWR identified as "1500 atmospheres".

Rigorous editing, too, might have reduced the frequency of use of such words as "plumped" (which, in the book's context has nothing to do with tumescence), eliminated such ugly neologisms as "routinized" and extirpated that meaningless nonce-term "world-class". This may be nit-picking but the fact that there are so many nits to pick suggests a significant degree of carelessness in preparation and raises the fear that such carelessness may extend to the serious matter of the work.

Another indication of an over-hasty production schedule is the quality of many of the line drawings which, in many cases seem to be reproductions of existing AECL material. In some cases – most notably the cutaway drawings of NRX and NRU – not only are the reproductions of poor quality, but are reduced in size to such an extent that nothing is clearly discernable but the printed labels.

Parts of *Nucleus*, especially those dealing with the earlier years, are excellent and one hopes they will be widely read. However, the history of AECL is, in part, driven by technical issues, and the author's failure to deal with these in a satisfactory fashion must rob the book of much authority.

David Mosey

Publications Noted

Losses of Off-Site Power at US Nuclear Power Plants, All Years Through 1987. Prepared by the Nuclear Safety Centre of the Electric Power Research Institute, NSAC-118, April 1988.

This compilation updates NSAC-111 which had similar data for all years through 1986.

The instances reported are "true" losses of off-site power, in other words the time for which off-site power was totally unavailable, as opposed to the time for which the plant in question operated without off-site power (i.e. on emergency diesels). Following a loss of off-site power a plant will switch to its own resources (diesels) and may not reconnect to off-site power as soon as it is restored (or back-up off-site power made available), but rather wait for a convenient moment to reconnect.

In 1987, NSAC reports three losses of all off-site power with durations of 1 h 58, 7 h 26 and 11 h. The eleven hour outage was due to weather conditions (wet snow, ice and salt spray) and occurred at the Pilgrim plant in November, and is the longest loss of power reported for all years. However this must be qualified by noting that the actual grid supply was restored within 1 hour while the station switchyard remained out of service for considerably longer while action was taken to remove salt spray deposits from the equipment. The Pilgrim plant had been in cold shutdown since April 1986.

The report notes encouraging evidence that the loss rate of off-site power continues to decline with loss rates for 1986 and 1987 about half the long-term average. This is attributed to corrective actions taken by plants which had experienced repetitive problems, improved redundancy in the newer plants' switchyards and a progressive increase in the subdivision of the grid.

Future losses of off-site power, the report notes, are expected to be mostly random.

Interested in Contributing to the *CNS Bulletin*?

To submit original articles, letters, FYI items, reviews, calls for papers, etc., contact one of the following:

- J. Nathwani, Editor, *CNS Bulletin,* c/o Ontario Hydro, 700 University Avenue, Toronto, Ontario, M5G 1X6.
- The *CNS Bulletin,* c/o the CNS office.
- Your branch or division representative.

***CNS Bulletin* Issue:**	**Editorial Deadline:**
January/February	January 1
March/April	March 1
May/June	May 1
July/August	July 1
September/October	September 1
November/December	November 1

Intéressés à contribuer au *Bulletin SNC*?

Pour soumettre des articles originaux, des lettres, des nouvelles, des revues, des appels aux communications, etc., veuillez bien entrer en contact avec l'une des personnes suivantes:

- J. Nathwani, Rédacteur, *Bulletin SNC,* a/s Ontario Hydro, 700 University Avenue, Toronto, Ontario, M5G 1X6.
- Le *Bulletin SNC,* a/s Bureau de la SNC.
- Le représentant de votre section locale.

Numéro du *Bulletin SNC*	**Date limite pour l'éditorial:**
janvier/février	le 1 janvier
mars/avril	le 1 mars
mai/juin	le 1 mai
juillet/août	le 1 juillet
septembre/octobre	le 1 septembre
novembre/décembre	le 1 novembre

CNS Branch News

Ottawa Branch News

Executive for 1988/89

The executive for the Ottawa Branch for the 1988/89 terms has been selected:

Chairman: Andrew J. Stirling

Secretary: Terry J. Jamieson

Treasurer: John D. Stewart

Members at Large: Fred C. Boyd
Robert L. Clarke
Daniel J. Gorman
A. David B. Woods

(Past Chairman): Joseph Howieson

Seminar Program

In what is hoped will become an annual event, the Ottawa Branch held its final seminar for the 1987-88 year in the form of a combined dinner and speaker.

The event, held on 12 May, was hosted at the Carleton University Faculty Club and featured Dr. Norman Tape, Director of Food Research, Research Branch, Agriculture Canada.

Dr. Tape discussed ongoing international activities in the area of food irradiation, including both social and technical issues. The results of various international studies on the issues surrounding food irradiation were presented along with a look at the recent Canadian House of Commons study (May 1987) on the subject.

Dr. Andrew Stirling of AECL was also in attendance, and mentioned additional material concerning the efforts of WNRE in the area of irradiation of food and other materials (much appreciated were the sample cookies made with irradiated flour!).

Many thanks to all our speakers and organizers for their efforts towards making the past year a very successful one.

Terry Jamieson

Toronto Branch

On May 2, 1988, the Toronto Branch held its final meeting of the 1987-88 season at the University of Toronto. The meeting, which was sponsored jointly with the University of Toronto Centre for Nuclear Engineering, featured a presentation by Dr. Eva Rosinger, Director of Waste Management Concept Review for AECL at the Whiteshell Nuclear Research Establishment.

Dr. Rosinger, who has worked in the nuclear fuel waste management field in both scientific and managerial capacities, spoke about the program to assess the concept of long term deep geological burial disposal of high level nuclear waste in plutonic rock in the Canadian Shield. The scope of the assessment

program will be determined by the Environmental Assessment panel and will include public meetings and AECB review. Scientific, public and regulatory approvals of the concept of deep geological disposal will all be sought before an actual development plan for a specific site will be proposed.

The geological disposal concept takes a multi-barrier approach to safety. Both natural barriers (characteristics of the geological medium) and engineered barriers (ceramic fuel, liner, cask, backfill) will be employed. The site which is eventually chosen must be economically not suited for mining, geologically stable and must have slow natural groundwater transportation. The CANDU fuel will be disposed of in the original form of fuel pencil bundles, without any reprocessing or chemical treatment (such as vitrification).

It was very encouraging to see that the assessment program will address not only the technical issues involved in this very important subject, but also the public concerns and acceptance which will be required in order to implement this last stage of the Canadian nuclear fuel cycle.

Eva Marczak

Nominations

The Toronto Branch Elections Committee has put forth the following nominations for executive positions on the Toronto Branch for the 1988-1989 season:

Chairman: Gord J. Sullivan, Ontario Hydro
Radioactivity Management and
Environmental Protection Department

Vice-Chairman: Ben Rouben,
AECL-CANDU Operations
Safety Engineering Department

Other Toronto Branch members in good standing who have previously served on the Branch Executive are welcome to apply for either of the positions listed above.

Eva B. Marczak, Ontario Hydro, Pickering NGS, will take up the position of Past Chairman, Toronto Branch.

Nominations for the following executive positions are also requested:

Treasurer
Secretary
Public Affairs Coordinator
Program Coordinator
Technical Coordinator
Education Coordinator

Position Available

McMaster University, Department of Engineering Physics

Postdoctoral Research

A postdoctoral position is available for research in collaboration with the undersigned faculty member, in the areas of thermal-hydraulic simulation and expert systems as applied to the nuclear environment. Send curriculum vitae, together with a statement of research interests, and the names of two referees to:

Wm.J. Garland
Department of Engineering Physics
McMaster University
1280 Main St. West
Hamilton, Ontario, CANADA L8S 4M1

Conferences and Meetings

Spectrum '88: International Topical Meeting on Nuclear and Hazardous Waste Management
Sponsored by ANS, cosponsored by U.S. DOE, Canadian Nuclear Society and others, to be held **September 11-15, 1988** in Pasco, Washington. For information contact: **Eva Rosinger, Whiteshell Nuclear Research Establishment, Pinawa, Manitoba, R0E 1L0,** (204) 753-2311.

Short Course in Reactor Safety
Sponsored by CNS/NSE, to be held in Toronto, Ontario, **September 19-20, 1988.** For information contact: **W. Midvidy, Ontario Hydro,** (416) 592-5543.

International Conference on Thermal Reactor Safety
Sponsored by ENS/ANS/CNS, to be held **October 2-7, 1988** in Avignon, France. For information contact: **H. Tamm, AECL/WNRE,** (204) 753-2311.

Tritium Safe Handling Course
Sponsored by CFFTP, to be held in Toronto and Chalk River, **April 25-29, 1988** and **October 3-7, 1988.** For information contact: **R. Matsugu,** (416) 823-0102.

12th International Conference on Plasma Physics and Controlled Nuclear Fusion Research
Sponsored by the IAEA, to be held **October 12-19, 1988** in Nice, France.

World Materials Congress
Sponsored by ASM, to be held **October 24-30, 1988** in Chicago, Illinois. For information contact: **A.R. Putnam,** (216) 338-5151.

ANS International Meeting.
Sponsored by ANS/ENS, to be held **October 30 to November 4, 1988,** in Washington, D.C. For information contact: **P.D. Stevens-Guille, Ontario Hydro,** (416) 592-6024.

International Symposium on Safety Standards and Practices for NPP
Sponsored by the IAEA, to be held **November 7-10, 1988** in Munich, FRG. Contact: **IAEA.**

Conference on Nuclear Power Plant Operation and Thermal Hydraulics
Sponsored by the KNS/CNS, to be held **November 14-17, 1988** in Seoul, South Korea. Contact: **K.H. Talbot, Ontario Hydro,** (416) 592-8216.

Conference on Use of Elastomers and Polymers in the Nuclear Industry,
sponsored by CNS/D&M, to be held **February 20-21, 1989** in Toronto, Ontario. For information contact: **Mr. E.G. Price, AECL/CANDU Operations,** (416) 823-9040

15th Annual Symposium on Waste Management '89
Sponsored by ANS/ASME , to be held **Feb. 26--Mar. 2, 1989,** in Tucson, Arizona.

International Conference on Availability Improvements in Nuclear Power Plants
Sponsored by the Spanish Nuclear Society/CNS/IAEA/ENS, to be held **April 10-14, 1989** in Madrid, Spain. For information contact: **K. Talbot, Ontario Hydro,** (416) 823-9040.

CNA/CNS Annual Meeting
To be held **June 4-7, 1989** in Ottawa. Contact: **P. Fehrenbach/T. Jamieson, AECL/CRNL,** (613)-584-3311.

5th International Conference on Emerging Nuclear Energy Systems
Sponsored by ANS/ENS/CNS, to be held **July, 1989** in Karlsruhe, Germany. Contact: **A. A. Harms, McMaster University** (416)-525-9140.

World Energy Conference: Energy for Tomorrow
To be held **Sept. 18-23, 1989** in Montreal. Contact: **TPC** (514)-878-3124.

IAEA Seminar on Research Reactors
Sponsored by the IAEA, to be held **September, 1989** in Chalk River, Ont. Contact: **P. Simpson, AECL/CRNL.**

Specialist Meeting on "Look-Before-Break"
Sponsored by CNS/OECD/NEA, to be held **Oct. 25-27, 1989** in Toronto. Contact: **L. Simpson, AECL/WNRE,** (204)-753-2311.

4th International Topical Meeting on Nuclear Reactor Thermal Hydraulics
Sponsored by KFK/ENS/ANS, to be held **Oct. 10-13, 1989** in Karlsruhe, Federal Republic of Germany. Contact: **J.H. Kim, EPRI,** (415)-855-2000.

International Waste Management Conference
Sponsored by ASME/ANS/CNS, to be held **Oct. 23-28, 1989** in Kyoto, Japan. Contact: **R. Kohout, Ontario Hydro,** (416)-592-5384. See **Call for Papers.**

Call for Papers

1989 Joint International Waste Management Conference

October 23-28, 1989 Kyoto, Japan

The conference is sponsored by the American Society of Mechanical Engineers, the Japan Society of Mechanical Engineers, and the Atomic Energy Society of Japan.

Papers are solicited from the U.S. and internationally for this conference covering the following radioactive waste management topics:

High-Level Waste and Spent Fuel Management

- International Update of High-Level Waste Management Activities
- Fuel Reprocessing/Waste Management – Developments and Issues
- Transportation of High-Level Wastes
- Spent Fuel Storage Systems and Experience
- Spent Fuel Conditioning for Disposal
- Back-End Fuel Cycle Economics
- Acceptability of HLW Forms for Disposal
- HLW Disposal Technologies and Institutional Issues

Low- and Intermediate-Level Waste Management

- International Update of Low- and Intermediate-Level Waste Management Activities
- Liquid Waste Processing Experience
- Waste Volume Reduction and Solidification
- Incineration – Development and Experience
- Solid Dry Active Waste (DAW) Minimizing/Processing
- Recent Waste Processing Technology Development
- Chemical Toxicity in Waste – Impact on Treatment and Disposal
- Waste Array and Characterization – Development and Experience
- Low- and Intermediate-Level Waste Disposal Trends
- Decontamination Waste Treatment/Disposal
- Waste Management in Developing Countries

Three copies of a 600-800 word summary should be submitted by **Sept. 2, 1988** to the Technical Program Chairmen as follows: **Mr. S.C. Slate** (high-level waste) Fax: 509-376-1867; or **Mr. F. Feizollahi** (low- and intermediate-level waste) Fax: (415)-768-9038. All summaries will undergo a final review by the Conference Technical Committee on September 15, 1988, in conjunction with Spectrum '88 radioactive waste management meeting in Pasco, WA, USA. Authors will be notified of paper acceptance by October 14, 1988. Completed papers will be due to the respective Technical Program Chairmen by February 15, 1989.

Quality in Nuclear Power Plant Operation Learning from Each Other

September 10-14, 1989 Toronto, Canada

Papers are solicited for the following subject areas:

- Implementations of Quality Principles and Practices
- Excellent Quality Management Practices
- Influence of Human Factors on Plant Performances
- Measuring Effectiveness of Quality Management Systems
- Future Trends in Quality Management Systems

Submit summaries (300 words) before Sept. 15, 1988, to:

Derek J. Battle
Canatom Inc., 55 Queen St. E., 9th Floor, Toronto, Ontario.
Fax (416) 367-3247,
Telex 065-24582.

International Conference on Availability in Nuclear Power Plants

April 10-14, 1989 Madrid, Spain

Program content:

- Mechanisms to Improve Availability
- Design Improvements
- Operating Experience Feedback

Submit summaries (900-1500 words) before Sept. 1, 1988 to:
Mr. J. Palomo, c/o SIASA, Paseo de la Habana, 134, 28036 Madrid, Spain.
tel: (34-1) 259.1422, (34-1) 457.4891, telex 46999.

The Unfashionable Side

Fahrenheit 212

The dramatic announcement in the January 11 edition of the *Montreal Gazette* that heavy water cannot boil triggered major reverberations throughout the Canadian nuclear power industry and the regulatory authority. A large part of the nation's telephone and telex network locked into temporary stasis as scores of frantic safety analysts overloaded the system with their desperate calls for mutual assistance. At least two large mainframe computers choked on the new assumptions in the codes they were running and disgorged nothing but question marks or short phrases of laconic impenetrability such as "refer to drawer" or "insert a quarter for another game". After a few days of this disorganized confusion the head of the regulatory authority Took Charge. The Big Z summoned the national leaders of the nuclear safety business to a meeting in Toronto. Person to person. If confusion must exist, he stated, let it be organized.

It is doubtful if there has ever been such an assemblage of power and influence since Margaret Thatcher chaired the meeting of the Ninth Directorate of the KGB at Basingstoke in 1982. Rob Roy was there. So was the Ayatollah Meneley. Giovanni Romano represented the analytic side, while operational safety was covered by the elegant and languid Algernon Scunthorpe-Overbury. A phalanx of analysts and engineers crowded the far end of the table, chattering like starlings and belabouring the table (and sometimes each other) with thick wads of computer printout. Rapping the hilt of his claymore on the table, Rob Roy brought the meeting to order then handed things over to the Big Z.

"I don't have to tell you why we're here", he said with his customary informality, provoking sycophantic chuckles from the toadies positioned strategically among the crowd. After a short pause to shuffle his papers he continued, "The news that heavy water can't boil was as big a shock to us at the Board as it must have been to you. But remember – let's treat this as an opportunity, not a problem. I'm sure that we can brainstorm this thing out and get some creative suggestions on the table. Let's have a good off-the-record, no-holds-barred discussion!"

There was a brief silence, broken only by the sound of Rob Roy grunting into the telephone. Then a babble of suggestions and counter suggestions burst forth.

" – now critical channel power is only set by centre-line melting!"

" – uprate by 80 per cent – "

" – take operating pressure down to atmospheric – "

But suddenly the cool voice of the Ayatollah cut across the enthusiastic patter of the brainstorm like an airlock door slamming. "You seem to be forgetting the ramifications of this discovery" he murmured, "the fact that heavy water no longer boils imposes some new requirements on some of our safety systems and trips – some conditioning signals and containment isolation signals are predicated on the assumption of boiling, I seem to recall". There was a stunned silence. The Ayatollah continued, "And I believe there's the small question of the requalification of certain equipment and structures to withstand 300°C water".

A latent pause ensued, broken by the voice of the Big Z. "The Ayatollah has described matters with his usual cogency and precision" he said, his tones hardening with decision, "and I feel that in view of the unprecedented nature of the situation we must call upon unprecedented resources – I mean Bauer and Worthing".

There was a sudden scrunching sound as the telephone handset shattered in Rob Roy's convulsive grip. An almost palpable wave of shock and horror swept around the table. A sound like a laryngitic parrot escaped the lips of the normally imperturbable Scunthorpe-Overbury. "You mean I'm going to have to change the locks on the computer room *again*?" whispered Romano, with incipient

CNS Council and Branch Chairmen 1987—1988
Conseil de la SNC et responsables locaux 1987—1988

President / *Président*
Ken Talbot (416) 839-1151

Vice-President / *Vice-Président*
Eva Rosinger (204) 753-2311

Immediate Past President / *Président sortant*
Irwin Itzkovitch (403) 998-6911

International Liaison / *Liaison internationale*
Peter Stevens-Guille (416) 592-5211

Secretary / *Secrétaire*
Gil Phillips (613) 687-5581

Treasurer / *Trésorier*
Art Pasanen (416) 823-9040

Communications / *Communications*
David Mosey (416) 592-8626
Keith Weaver (416) 592-6771

Membership Chairman / *Président du Comité du sociétariat*
Troy Lassau (416) 822-4111

Program Chairman / *Présidente du Comité du programme*
Hugues Bonin (613) 541-6613

Branch Activities Chairmen / *Présidents du Comité des activités des sections locales de la SNC*
Joe Howieson (613) 234-8103
Phil Ross-Ross (613) 584-2535

CNA/CNS Relations / *Inter-relations ANC/SNC*
Ken Talbot (416) 839-1151

Education/Public Affairs / *Éducation/Affaires publiques*
David Mosey (416) 592-8626

Policies & Procedures / *Politiques*
Prabhu Kundurpi (416) 592-7667

Ex-Officio / *Ex-Officio*

CNS Division Chairmen / *Présidents des divisions de la SNC*

- **Nuclear Science & Engineering / *Science et ingénierie nucléaires***
  Bill Midvidy (416) 592-5543
- **Design & Materials / *Conception et matériaux***
  Ed Price (416) 823-9040
- **Mining, Manufacturing & Operations / *Exploitation minière, fabrication, exploitation des centrales***
  Al Lane (613) 584-3311
- **Waste Management and Environmental Affairs / *Gestion des déchets radioactifs et environnement***
  Peter Stevens-Guille (416) 592-5211

CNS 1989 Annual Conference Chairmen / *Présidents de la conférence annuelle de la SNC (1989)*
Paul Fehrenbach (613) 584-3311
Terry Jamieson (613) 236-8423

CNS General Manager and CNA Liaison / *Directeur-général de la SNC et agent de liaison de l'ANC*
Jim Weller (416) 977-6152

CNS Branch Chairmen / *Responsables locaux de la SNC*

Chalk River	Joan Miller	(613) 584-3311
Québec	M.L. Ross	(819) 298-2943
Ottawa	Joe Howieson	(613) 995-1118
Toronto	Gord Sullivan	(416) 592-7365
Manitoba	Kishor Mehta	(204) 753-2311
New Brunswick	C.K. Scott	(506) 453-4520
Central Lake Ontario	Dan Meraw	(416) 623-6606
Bruce	Karel Mika	(519) 368-7031
Golden Horseshoe	Bill Garland	(416) 525-9140

hysteria. "I believe the combination of Bauer and Worthing will dictate precautions of a much more comprehensive nature than *that*" Scunthorpe-Overbury observed with languid elegance. "I wish you'd stop being languidly elegant S-O" growled Rob Roy, looking around for a new telephone. "That's not languid elegance" snapped Scunthorpe-Overbury with uncharacteristic vehemence, "it's ironic wit. I wish you'd learn the difference".

The sense of common purpose, which had hitherto informed the meeting, began to disintegrate as various conversational sub-groups formed to exchange horror stories from the Bauer-Worthing mythology. Accusations and counter-accusations began to fly about. Matters were not improved when Scunthorpe-Overbury suggested (somewhat tactlessly, in view of the topic under discussion) that "we should boil up the kettle and have a nice cup of tea".

Once more it was time for the Big Z to exert his authority. "Gentlemen", he began courteously if inaccurately, "I really must suggest most emphatically that Bauer and Worthing be retained. If you cannot see your way clear to doing this, then you leave me with but one alternative – and he gestured menacingly at a sheaf of pre-printed "show cause" letters that lay at his elbow. A gasp of horrified agreement ran around the table.

Bauer and Worthing were located swiftly and flown to Toronto by helicopter. In accordance with Ontario Hydro's usual policy with respect to consultants they were provided with office space at the utility's downtown headquarters. This, however, proved to be less than totally effective. Bauer's epicurean and juponic proclivities proved to be a little too distracting for regular staff working in his immediate vicinity. And as Worthing had insisted on installation of his steam driven Difference Engine, which was not at that time operating in the condensing mode, temperature and humidity levels in the office soon rose to Amazonian jungle levels, resulting in the rapid growth of a wide range of strange organisms on the nearby potted plants. Besides, the cleaning staff began to complain about the empty brandy bottles.

This situation was resolved by placing the two eminent investigators in suites at the prestigious downtown Hydride Regency Hotel. While the expenses thus incurred were heavy they were felt to be well worthwhile. Indeed, as Scunthorpe-Overbury noted in an internal memorandum: "The latest bill from the Star and Garter Spring bar (relating to 'technical meetings') is quite modest in the context of the economic penalties imposed by a forced shut-down of a single nuclear plant".

Within a week of removing to their new accommodation, Bauer and Worthing had prepared interim reports. Both documents were massive and comprehensive reviews of the situation. Bauer created a certain amount of mystification by his heavy reliance on Bishop Berkeley and Descartes, his concluding references to the work of Jean-Paul Sartre and his repeated invocation of Maxwell's Demon. Worthing's more technical approach, rooted as it was in the early theories of I.A. Richards and F.R. Leavis, was initially more understandable (as far as Page 2 at least) but his *Variorum* text and *Concordance to the Steam Tables* aroused equal measures of irritation and incomprehension as did his repeated insistence upon the establishment of an "objective correlative".

But while these reports were working their way through the 64-name distribution list Bauer and Worthing were not idle. Following an intensive 18 hour technical meeting in the Star and Garter Spring they prepared their *Final Report and Recommendations* – a document which in its elegant simplicity, unequivocal resolution of the issue and technical lucidity must rank as a classic in scientific literature. With uncharacteristic modesty (but totally characteristic evasiveness) the two researchers insist that each had an equal share in preparing the report – and a close study of it seems to bear this out. While the Bauer-Worthing report's findings are probably familiar to all in the nuclear business, they are summarized here for the benefit of the non-specialist.

1. The fact that heavy water cannot boil may be good news for routine CANDU reactor operation but raises severe problems under (ad-mittedly very unlikely) accident conditions, par-ticularly in such areas as containment button-up and negative pressure system activation.

2. Any solution to these problems should not be predicated upon use of natural water (i.e. H_2O) since the pace of scientific discovery suggests that it may not be too far in the future when H_2 is determined to be incapable of boiling.

3. Since void formation in a CANDU reactor core is undesirable, and since all safety assessments should be conservative, a very generous margin of conservatism will be gained if, for an unbroken coolant circuit, *heavy water is assumed to boil as before.*

4. Under accident conditions heavy water cannot be assumed to boil. Those systems hitherto triggered by vault pressure rise would instead be activated by rapid-response heat sensors located at vault floor level and in the sumps.

5. An arrangement of deflector plates, gutters and drainpipes should be installed to direct leaking high-pressure high-temperature D_2O to the building sumps.

6. A high capacity cooling system should be installed to provide rapid cooldown of 300°C heavy water. In view of the possible future problems with water, as noted in (2), some alternative heat transfer medium was recommended. Mercury, liquid sodium or lead-bismuth were possibilities.

Masterly as this assessment was, it is almost eclipsed by the final recommendation to the effect that much further work need to be done in this important area, especially with respect to modifications to the secondary side of the reactor system which relied "to an imprudent degree" upon the assumption that water boils.

The impact of the Bauer-Worthing report was dramatic and immediate with retro-fitting beginning at some installations within the week. At the time of writing initial modifications should be complete on all CANDU units operating in Canada. Bauer and Worthing remain on long-term contract to resolve the secondary side problems they identified – a situation of particular value for Worthing since he is urgently seeking a new working fluid for his Difference Engine. And a number of senior technical staff from the operating utilities and the regulatory authority remain on "extended medical leave".

Quentin Vernon